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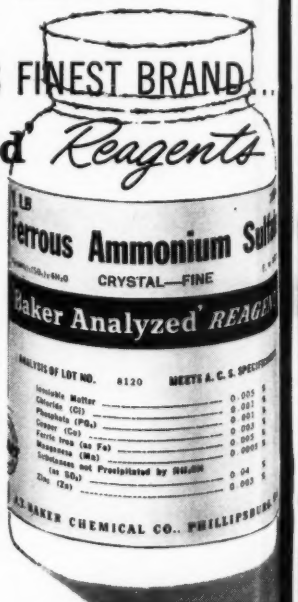
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VOLUME 32

October, 1955

NUMBER 10

JOURNAL OF

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Subscription Price: Domestic $3.50 per year; Countries in Pan-American Union $3.50 per year; Canada $4.00; other countries $4.50. Issued monthly. Single copies of issues in current year, 50¢ each; all other single copies, one dollar. Foreign remittances must be accompanied by International Money Order.

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The JOURNAL OF CHEMICAL EDUCATION is the official organ of the Divisions of Chemical Education and History of Chemistry and incorporates the Report of the New England Association of Chemistry Teachers, and the Proceedings of the Pacific Southwest Association of Chemistry Teachers. It is indexed in the Education Index, Industrial Arts Index, and, in part, in the Quarterly Cumulative Index Medicus.

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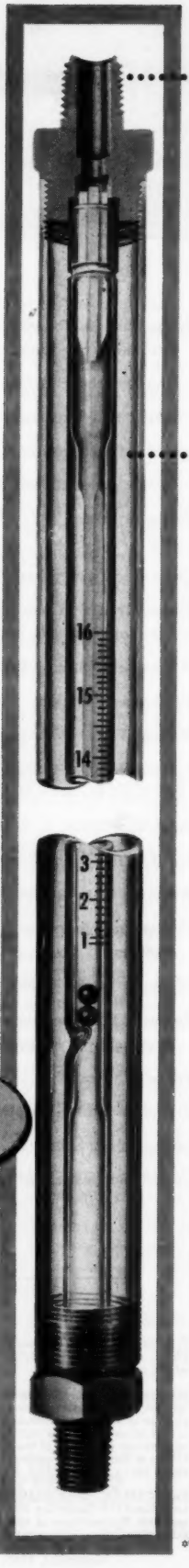

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10. GROUP ZERO (INERT GASES) AND THE ATMOSPHERE

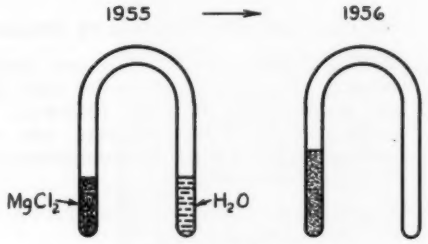
A. ATMOSPHERIC PRESSURE

*10-1 Mercury barometer. Gallon tin can containing 50 ml. water, set on tripod over burner; rubber stopper for can; glass jar, large enough to hold can, half-full of water. **Heat water until steam issues from can, stopper tightly, quickly plunge into cold water. Can collapses. Contrast with mercury rise in barometer.**

10-2 Rubber balloon or balloon-doll only one-quarter inflated, in bell jar attached to vacuum pump. **Show inflation of balloon as air in jar is exhausted.**

B. SUBSTANCES PRESENT IN AIR

10-3 *Water.* See Figure 10-3 a continuation of experiment 4-7, deliquescence.



DELIQUESCENCE

Figure 10-3

10-4 *Oxygen.* Show the presence of oxygen in air by three experiments.

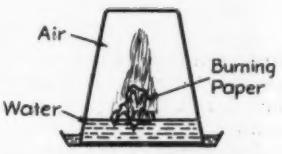
(a) The slow oxidation, rusting of steel wool, Figure 10-4a, as in 2-13.

SLOW OXIDATION

Figure 10-4a

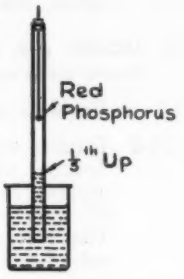
(b) Burning of a piece of paper in a dish of water, covering burning paper with a glass. See Figure 10-4b. Discuss this carefully with the class.

(c) Burning of phosphorus in air; see Figure 10-4c. Red phosphorus, burner. Rubber stopper carrying a deflagrating spoon which extends down into a 2 × 50 cm. glass tubing which is clamped vertically, with its lower end immersed in a 600 ml. beaker nearly full of water. **Ignite a spoonful of red phosphorus and lower it into the glass tubing, stoppering tightly. Oxides of P form and dissolve in the water, which rises one-fifth the height of the air column. Shows air is 1/5th oxygen.**



PAPER BURNING IN AIR
(Why 1/5th Up ?)

Figure 10-4b



% O_2 IN THE AIR

Figure 10-4c

*10-5 *Nitrogen.* Covered nickel crucible half-filled with powdered Mg and placed in triangle on tripod over burner; tongs, litmus paper, clock-glass to cover 600 ml. beaker. **Heat Mg three minutes, cool, plunge crucible into water (CARE). Place moistened litmus paper across clock-glass over beaker. *Forms* Mg_3N_2, and from this NH_3 which turns litmus blue.**

*10-6 *Carbon dioxide.* Limewater on clock-glass overnight. Two test tubes with two 6 mm. L-shaped tubes to blow through; one tube

Turn the page for additional demonstrations

***Footnotes**

10-1 The can will also collapse if left on the table.
10-5 Keep face away from beaker when plunging the crucible into water; often there is a flare when unburned red-hot Mg strikes the water.
10-6 Give the tube of water to the class wit; ask class to guess what is being used to dissolve the $CaCO_3$.
10-10 Be extremely careful not to spill any kerosene into the liquid air, since it forms an explosive mixture.
10-11 Caution class not to clasp frozen fruit tightly, or cold-burn will result.
10-14 This is a difficult, but striking, experiment. You will need to practice it beforehand.
10-15 Tennis balls with wrappers removed are good. The rubber must not be too thick. Allow plenty of time for the rubber to freeze.
10-21 Play safe! Hold cigar or cigarette in tongs, not the hand. Oils in the tobacco might form an explosive mixture with liquid air.
10-23 Mr. Birdseye, visiting Laborador, noticed that the natives quick-froze fish by holding them in the chilly air at −30° C; they would remain thus preserved indefinitely. The present quick-freeze process duplicates this, forming tiny frost crystals (slow crystallization gives large crystals) which do not rupture membranes as slow-freeze would.

Labels for Topic 10. (For code, see instructions for assembling kits, J. Chem. Educ., **32**, 12A(1955).) 10-2-*J*-four balloons, 10-3-dropper with curved tip—H_2O, 10-4-*w*-red P, 10-5-*J*-nickel crucible, 10-5-*w*-Mg powder, 10-6-*N*-limewater, 10-6-*N*-HCl aq., 10-10-*w*-ten gram wt., 10-10-*N*-kerosene, 10-10-*w*-string for wick, 10-11-*J*-cranberries, 10-13-*w*-$K_2Cr_2O_7$, 10-14-*J*-two lead wires with weights, 10-17-*J*-corks for special tube, 10-20-*w*-lumps charcoal, 10-20-*w*-iron wire, 10-21-*J*-four cigarettes, 10-21-*J*-cotton.

half-filled with water, other half-filled with limewater; HCl-aq. **Show limewater on clock-glass becomes cloudy. Have race between two students, blowing through solutions, showing contents of one tube turns cloudy. Dissolve $CaCO_3$ with HCl.**

10-7 *Inert gases.* Neon signs, Geissler tubes of the gases in the atmosphere. **Light the tubes, showing different colors.**

C. LIQUID AIR EXPERIMENTS (about 5 liters of liquid air is needed.)

Liquid Air is Cold

10-8 Rubber tubing from gas-tap leading to an L-tube which passes through a 2-holed stopper to bottom of test tube; exit tube 6″ long with nozzle; rubber policeman. **Pass slow stream of illuminating gas through tube, lighting at nozzle; gives a yellow flame from hydrocarbons. Immerse tube in liquid air for three minutes; gradually the flame becomes blue as hydrocarbons are frozen out and H_2 alone continues to burn. Remove tube from liquid air, afix rubber policeman to inlet tube. Solid methane in tube continues to evaporate, can be re-lighted; flame bigger when tube warmed with palm of hand.**

10-9 Coffee pot on cake of ice; burner. **Pour 50 ml. liquid air into pot; put lid on pot, appears to boil on ice. Hold over burner flame; white crust of dry ice forms on bottom of pot.**

*10-10 Weight on string lowered into test tube half-full of kerosene; scissors, candle-stick. **Make sure no kerosene on outside of tube (CARE: EXPLOSIVE) then lower tube into liquid air. After few minutes kerosene freezes. Remove tube, run tap-water on tube to release solid kerosene. Place in candle-stick, trim wick, and light this kerosene candle.**

Change of Properties at Low Temperatures

*10-11 Half-a-dozen cranberries or grapes in 400 ml. beaker. **Cover with liquid air. In few minutes shake beaker and berries rattle like marbles. Throw to audience.**

10-12 A carnation or other fluffy flower. **Dip into liquid air. Crush in palm of hand.**

10-13 Two test tubes of coarsely-powdered $K_2Cr_2O_7$. **Pour liquid air into one; hold two tubes side-by-side, showing colder one is paler.**

*10-14 Two lead wire spirals with weights just heavy enough to extend them; ring stand, clamp. **Immerse one spiral in liquid air three minutes. Lift ring so as to elevate both spirals simultaneously; cold one remains springy, other sags.**

*10-15 Hollow rubber ball in 400 ml. beaker. **Bounce ball, showing elastic. Then cover with liquid air three minutes. Hurl against wall: ball shatters. Do not pick up fragments until warm again.**

10-16 Hot dog on a chain, hammer. **Soak in liquid air three minutes. Smash with hammer.**

Pressure Generated upon Evaporation

10-17 Thick Pyrex brand test tube, towel, 10 corks. **Pour liquid air into tube *wrapped in a towel;* stopper: corks pop *at* audience.**

10-18 Steam engine with chimney provided with funnel for pouring in liquid air; stopper for funnel. **Pour in liquid air, stopper funnel; engine runs, and whistle works on liquid air instead of on steam.**

Nitrogen Evaporates First, Leaving Oxygen

ATTENTION! CARE! Do not ignite a mixture of aluminum powder and liquid air, as described in THIS JOURNAL. The author knows three lecturers who were seriously injured when the aluminum-oxygen mixture detonated.

10-19 Repeat 2-9, liquid air evaporating from cylinder of water.

10-20 Lump of charcoal, iron wire, tongs, 100 ml. beaker, burner. **Heat red hot; immerse in liquid air: charcoal and wire continue to burn fiercely.**

*10-21 Cigarette, cigar, cotton, 100 ml. beaker tongs. **Soak in liquid air *hold in tongs;* ignite (CARE), rapid to violent burning.**

Liquid Air on Animals

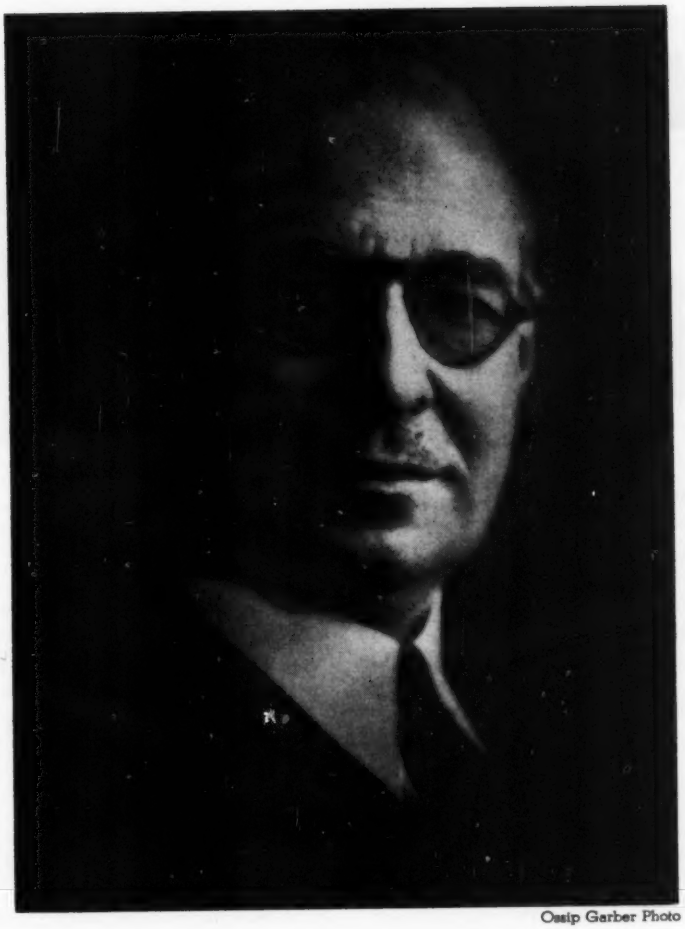
10-22 **Pour on hands, in mouth. Experiment with small quantities first! *Do not swallow!***

*10-23 *Quick freeze.* Gold fish in bowl, net, deep-freeze vegetables, 400 ml. beaker. **Pour liquid air on fish for 10 seconds (no longer), throw into water; fish appears dead, presently revives and swims away. Explain this principle of quick-freeze producing tiny frost crystals.**

Next month's Tested Demonstrations in General Chemistry

11. METALLURGY

For a complete list of topics for 1955–6 see J. Chem. Educ., 32, 28–9(1955)



Ossip Garber Photo

Henry Clapp Sherman

(See page 510)

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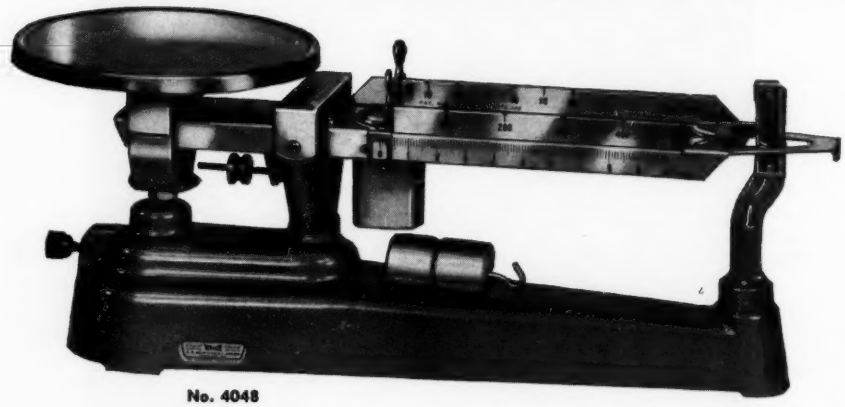

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Editor's Outlook

It is a most humbling and not a little terrifying experience to realize that the paper in front of us is to hold thoughts which may be inspected by nearly 10,000 readers. Frankly, we have to get an edge-of-the-cliff grip on ourselves when we think of the monthly glare of the clear empty sheet which often may be matched by the blankness of mind which no flow of ink can conceal. The camouflage of the editorial plural also feels particularly thin when we realize that among our readers may be many of the occupants of the pedestals in our private Hall of Fame. They are joined, we are sure, by many others less familiar to us who are better qualified to hold this pen. It is sobering, too, to share an editorial office with 31 bound volumes. This is a legacy of vision, devotion, and sheer hard work for which we are humbly grateful. It is part of the really plural "we" to whom an editor owes his greatest debt.

In terms of the present tense, the justification for the "we" which will appear on these pages is far more than the conventional editorial prerogative. Dr. Rakestraw's comments last month state the case. Along with the typewriters and blue pencils being shipped to Wooster come bulging files of correspondence. This is the real editorial office of THIS JOURNAL. Manuscripts are in all stages, from page proof down. Some are only good ideas in hopeful letters to prospective authors. The replies of manuscript referees, book reviewers, and editorial associates bear hundreds of different signatures. Many replies to past reader-interest surveys have been accompanied by thoughtful letters. There is even a "crack-pot" file!

We count heavily on the contents of one file as we plan ahead. It is the "This-is-what-the-JOURNAL-ought-to-be" correspondence. The spectrum of THIS JOURNAL's readership is wide indeed. High-school teachers may be followed on the subscription list by men specifically interested in the pedagogy of graduate-level instruction. The newly-hatched, degree-bearing college instructor may be followed by the oil-company executive who for 40 years has sublimed his hankering for teaching by thus keeping up with the classroom. The intimate coziness which characterized THIS JOURNAL's early years of service to its readers hardly can be duplicated now, even to the membership of the Division of Chemical Education. Twenty-five hundred is a big number to serve "family style." To return to the spectrum analogy, we hope to be able to study the emission as well as the absorption characteristics of our readership.

What we hope we can do is to let THIS JOURNAL speak for itself when we are asked: "What is the editorial policy?" An editorial policy is like a pesky colloid—sometimes it just will not coagulate. One of the best precipitants for this one is the phrase probably invented by THIS JOURNAL's first editor: "The JOURNAL OF CHEMICAL EDUCATION is a living textbook of chemistry." Along with this in our own mind we have added the conviction that we are facing the exciting task of editing a journal for *students* of chemistry. Those among our readers who do not think of themselves as such may be disappointed. In fact, we almost hope they will be.

*Symposium on Pioneers in Chemistry at Columbia**

INTRODUCTORY REMARKS

LOUIS P. HAMMETT
Columbia University, New York, N. Y.

THIS symposium honors four men who, each in his time and in his own way, pioneered in an important way in the advancement of science. It is fitting that we should pay tribute to their accomplishments in the year in which the university with which each was connected throughout his professional life is celebrating the two-hundredth anniversary of its founding. It is equally fitting that we should examine the lives of men like this in the hope of obtaining guidance for our own actions. This symposium is presented by the Division of History of Chemistry, and it is an important function of history to study the ways in which men have behaved in the past in order that we may predict their behavior in the future. We can learn much that is helpful for the critical problems of our difficult times from the careers of these men.

There can be no question that science now affects the lives and welfare of people generally more intimately and more vitally than ever before, and there is no doubt in anybody's mind that the results of scientific discovery are of the utmost importance for the defense and protection of our nation. And yet it would be foolish to deny the prevalence of a misunderstanding which approaches antagonism between scientists and their nonscientific neighbors. It seems to me that the very crux of this difficulty lies in the matter of pioneering, of breaking away from established patterns and habits.

To the scientist it is self-evident that major scientific advance depends upon the pioneering genius, that is, that it depends upon exploratory research in areas which have no immediately obvious practical value, carried out by people of outstanding and exceptional ability. And yet many scientists feel that the public generally and their elected and appointed representatives in particular think of scientific work as a matter of routine plugging in which the result can be predicted in terms of man-hours of effort. Most scientists are appalled by the indications that government does not feel the need of the genius, that it wants only the thoroughly disciplined, even if this implies the thoroughly dull employee. They are frightened by the apparent prevalence of the Maginot-line mentality which is more concerned with the preservation of secrets than it is with the effort to advance more rapidly than the enemy does. No one can feel that this is a healthy situation or one conducive to the exercise of those highest functions of the creative imagination upon which all great discoveries depend. Living under these conditions it is well to remind ourselves that scientists have differed with government in other times than these and have sometimes been able to mold and lead public opinion to the public good. I know of no better example of this than the career of Charles Frederick Chandler.

We may also with profit examine the environment in which these four men worked, an environment whose character and quality they helped largely to form. This is a university department of chemistry which has always had and still has its own highly characteristic attitudes. It is the kind of a department in which Bogert could become an outstanding leader in the training of organic chemists by his own inspiration and effort at a time when a background of European training was generally thought to be obligatory. It is a background in which Sherman could start as an analytical chemist, specializing in the analysis of foods, and become one of the chief architects of the new science of nutrition. It is a department in which Nelson could adventure in two new directions, one in what would now be called physical organic chemistry, the other in the quantitative study of enzymes, at a time when the pattern of activity of the organic chemist was in most institutions frozen into narrowly defined limits. It is a department in which Beans started as a synthetic organic chemist and became a leader in the modern teaching of analytical chemistry. It is a department in which La Mer, whose doctorate was earned in food chemistry, could become first a leader in theoretical electrochemistry, and later one of our outstanding colloid scientists.

It is therefore an institution in which individuality has always been encouraged, one where departure from established patterns has always been looked upon favorably, one which has had very little use for the

* Presented before the Division of History of Chemistry at the 126th Meeting of the American Chemical Society, New York, September, 1954.

kind of type-casting by which a man's whole scientific career is determined by his choice of a doctoral research problem. It is not the only kind of successful and highly useful department of chemistry, and it has its weaknesses as well as its strengths, but it is a kind of department which has played a valuable part in the advancement of science in this country and in the world. It is one which has deserved well of the public support which it has enjoyed and upon which every university department must depend. It is indeed one of the great strengths of our American society that university departments, like other institutions, do vary in character and organization, instead of conforming to a single type prescribed by a central government.

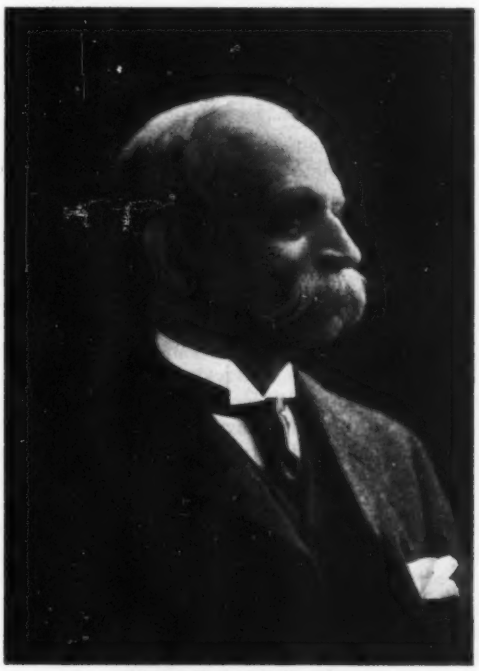
CHARLES FREDERICK CHANDLER

ARTHUR W. HIXSON
Columbia University, New York, N. Y.

In 1854, when Columbia College was celebrating its first centennial, a New Bedford, Massachusetts, dry goods merchant made a decision that was to have a profound effect on the university's second-century life and on the development of chemical science in America for generations thereafter. That merchant, acting on the strong advice of Professor Charles Joy of Union College, Professor Louis Agassiz of Harvard College, and a New Bedford High School science teacher, decided to send his 17-year-old son Charles Frederick Chandler, who had finished a year at Harvard, to Germany to study chemistry and other sciences at Berlin and Göttingen. Young Chandler, who had been passionately interested in scientific studies from early boyhood, was elated beyond measure. His year at Harvard was not a particularly happy one. Not only did he find the instruction in chemistry poorly organized and inadequate, but the college's general attitude toward science students was depressing. They were usually classified as being hopelessly deficient in Latin and Greek and metaphysics, with no background for cultural scholarship or dignified intellectual usefulness. In Chandler's words, "they were despised."

In the early morning of July 3, 1854, Chandler sailed joyously out of New York harbor as a guest on a whaling ship owned by a friend of the family. In the evening of that day he sat on the deck, limp from seasickness, when the captain passed by and remarked, "Young man, being a student of natural science, you are particularly fortunate in sailing on this trip. Tomorrow morning you will have the opportunity to observe a phenomenon rarely seen by passengers at sea. The sun will rise twice. Meet me here at five o'clock."

Chandler, feeling miserable but eager to see the rare phenomenon, staggered to deck at the appointed time where he found the captain giving orders to the crew.



Charles Frederick Chandler

Turning to him the captain said, "Follow that seaman aloft to the boom of the mainmast topsail. When you see the sun appear on the horizon, note the time and come back down to the deck at once where in a few minutes you will see it rise again. I will wait for you."

Unsuspectingly Chandler obeyed his orders. When the observation was complete the captain remarked, "That is the first lesson in practical navigation and, by the way, a first principle of success. The sun will rise earlier for anyone who has the gumption to rise early and to the heights to see it."

"That vivid lesson," said Chandler near the end of his career, "was one of the most valuable lessons and bits of advice I ever received. I never forgot it."

After 34 languishing days at sea he arrived at Antwerp. This was followed by six weeks of intensive tutoring in German at the home of a friend in Cologne. Then, with a letter of introduction from Professor Joy and a gift collection of minerals, he set out for Göttingen where he was received with much courtesy by Professor Friederick Wöhler. The old professor, whose great contributions to both inorganic and organic chemistry had been made nearly 30 years before, was delighted with the minerals specimens which he added to his hobby, mineral collection, one of the largest private collections in Germany at that time.

Apparently Wöhler liked the American youth from the beginning. He assigned him to a place in his private laboratory where he worked "mit meisterhaften Fleisse." Chandler also was fortunate in being placed at once in the laboratory for advanced students under Wöhler's personal supervision. There he not only absorbed his great professor's knowledge and method, but availed himself of the opportunity to attend lectures in physics by Weber, in botany by Von Griesback, and in geology by Baron Wolfgang Von Walterhausen. At the end of a most stimulating year at Göttingen where, in Chandler's words, "the creative spirit of practical chemistry was deeply planted in my soul," Wöhler advised him to finish his studies at Berlin.

Through Wöhler's influence Chandler became the private assistant of Professor Heinrich Rose, the foremost authority in analytical chemistry of the time. There, in addition to the preparation of his doctoral dissertation, he studied with and was deeply influenced by some of the most productive scientific minds in Europe, notably Heinrich Rose in analytical chemistry, Gustave Rose in mineralogy, Heinrich Magnus in industrial chemistry, Heinrich Dove in physics, Johann C. Poggendorf, the great editor of *Annalen der Physik u. Chemie*, and Christian Ehrenberg in microscopy. From Heinrich Magnus, whose masterful lectures attracted students from many lands, Chandler learned the art of the experimental lecture in which he was to excel for more than half a century.

At the homes of the two Roses he made the acquaintance of Baron Alexander Von Humboldt, the world's greatest scientist of the time. The Baron became deeply interested in Chandler and his work and spent much time advising him on a "proper pattern for a scientific career in a country where the true nature and power of the natural sciences are practically unknown. The work of the pioneer," said the great scientist, "is slow and hard, but there is success at the end of the road. You will always be welcome to return to the fatherland to drink at the fountainhead of scientific studies from which the knowledge and spirit of creative science flow in an ever increasing stream."

Through Wöhler, Chandler made the acquaintance of Baron Justus Von Liebig at Munich who advised him to devote his life to teaching and research, and to applying chemical science to health, trade, and industry—advice which Chandler followed zealously to the end of his life.

After concluding his studies at Berlin, with letters of introduction from Wöhler and Christian Ehrenberg, the famous microscopist, he visited Louis Pasteur, the brilliant young professor of chemistry and dean of the faculty of science at the University of Lille. "I was deeply impressed," said Chandler, "by his modesty and complete lack of ostentation which made him stand out in marked contrast with some of my German teachers. I wished that I might work for a year in his laboratory but I did not have sufficient funds for that and was quite homesick besides."

In November, 1856, at the age of 19, Chandler returned to his home in New Bedford with the degrees of master of arts and doctor of philosophy from Göttingen and with the best education in chemistry and allied sciences obtainable in the world at that time. In a total of three years of collegiate and university studies he had accomplished with honors more than the average doctoral student accomplished in six years.

A TIME OF EXPANSION

What kind of an America did Chandler find when he returned in 1856? Practically every phase of social, economic, governmental, and educational activity was expanding rapidly. There was a decided upsurge in population growth. The nation was changing at a high rate from a total farm economy to a balanced manufacturing status centered in towns and cities.

Villages and towns east of the Mississippi rapidly were becoming cities with pressing problems of food supply, water supply, waste disposal, and public health.

Agricultural production was expanding at a notably increasing rate owing to the invention of labor-saving machinery, the rapid extension of railroad transportation, and the generous aid of the government in low-cost land settlement. A bill providing for subsidizing the establishment and operation of agricultural- and mechanic-arts colleges was being pushed through congress.

The discovery of gold in California seven years before alerted the nation to its great mineral resources. Mining and quarrying in general were expanding rapidly owing to the invention of the mechanical rock drill and the first successful mechanical rock crusher by Blake.

Whale-oil lamps and tallow candles were used extensively for home and public lighting. Coal oil was beginning to be used. The petroleum industry had not been born.

The Kansas-Nebraska act, which in the next three years was to fan the embers of the long smouldering sectional contest between the nation's free and slave economies into the consuming flames of a civil war, was

being debated in the congress almost to a point of violence that was rocking the nation.

Although waterpower and steam were used to some extent in manufacturing and transportation, by far the greatest part of the nation's work was done by man- and horsepower.

Although chemical industries had been established in the colonies as early as 1635 by Governor John Winthrop of Connecticut, they comprised but an insignificant fraction of the nation's total. They were principally very small, inorganic-chemical enterprises that did not amount to enough to warrant a special classification. There were very few places in America where even the most elementary education in chemistry could be obtained. With the exception of Yale and Amherst, advanced courses in chemistry in American colleges were practically nonexistent. The only able teachers of chemistry in American universities were a few who had studied in French and German universities and who were fighting what seemed to be a losing battle with the classicists to get their subject recognized as a respectable college discipline.

Generally the instruction in chemistry consisted of a few lectures and experiments in courses in natural philosphy that included physics, mineralogy, geology, medicine, pharmacy, botany, zoology, and anything else in which the professor happened to be interested. There were no professional chemists. Most of the chemical technical advice came from drug manufacturers, druggists, country doctors, household and medical recipe books, almanacs, itinerant nostrum makers and soap boilers, and similar sources of proprietary science. Chemical advice for the establishment of important chemical enterprises was imported from Europe. That is what the ambitious young scientist found when he returned to his homeland, a country, as Von Helmholtz had told him, "where the nature and power of the natural and physical sciences were all but unknown."

FROM JANITOR TO FULL PROFESSOR

Chandler immediately set himself up in New Bedford as an expert consultant in oil technology. He quickly found out that there was so little demand for his services that he could not make a living. What was there left but teaching? He wrote to his old friend, Professor Charles Joy at Union College, telling him of his difficulties. Joy replied that he knew of no opening in industry at the time but that he was looking for an assistant; however, the pay was very low. Chandler did not wait to make a formal application for the job but went to Schenectady at once. When he arrived he found that there was no money in the budget for an assistant but there was $400 for the employment of a janitor. Chandler accepted the assistantship with the title of janitor. Not only did he do the work of a full-time assistant, but did the janitorial work as well. He had been there only three months when Joy resigned to accept the professorship of chemistry at Columbia College.

Joy recommended Professor J. W. Mallet of the University of Alabama, one of the best known teachers of chemistry in the United States, to be his successor. However, Union's colorful president, Eliphalet Nott, who had liked the way Chandler had taken hold of the work both as assistant and janitor, called him to his office. "Young man," said the 80-year-old president, "if you can handle the lecture work in chemistry as well as Professor Joy did, I will appoint you to succeed him and will raise you to a full professorship when you have reached the age of 21." Chandler thought he could do it and would like to try it. Thus began one of the most dynamic and successful teaching careers in the annals of American chemistry.

His success as a teacher was immediate. He quickly advanced to rank of professor and head of the department. In the seven years of his tenancy there he taught general chemistry, crystallography, mineralogy, agricultural chemistry, geology, and assaying, and brought his department to top rank in the college. He soon became one of the most influential teachers in the college. Everything he took hold of took on new life. His reputation as a lecturer carried his influence far beyond the confines of the college. He never missed an opportunity to spread the gospel of the importance of chemistry in public health, agriculture, trade, and industry. He organized a science club with membership open to students, faculty, townspeople, men in industry, agriculturists, and in fact to anyone who was interested. It was a success from the beginning with members from Albany, Troy, and other nearby towns and cities. "There," said Henry Burden of Albany, the famous iron master of the mid-nineteenth century who was much impressed with Chandler's initiative and broad practical knowledge, "is a young man with the kind of vision and aggressive leadership that this nation needs greatly."

In 1864 Professor Thomas Eggleston, the famous metallurgist who had just founded the school of mines of Columbia College and who had been attracted by Chandler's remarkable success at Union College, offered him the position of professor of chemistry in the new institution at whatever salary he could get from the students' fees.

The trustees of the college who had reluctantly consented to lend Columbia's name to the venture were so skeptical of the success of the proposed radical and bold undertaking in professional education which would not require proficiency in Greek, Latin, and metaphysics as entrance requirements that they would not appropriate anything for salaries or operating expenses. In addition, the location of a school of mines in New York City when the mines of the country were hundreds of miles away seemed to some of them to be not only ill-advised but preposterous. Chandler, who could see the faint glow of a new industrial dawn arising in America from the wreckage of the Civil War, shared Eggleston's vision and enthusiasm and was willing to join in the venture. "A nation can only be great if its industry is great," said Chandler. "Its

industry can be great only if it is built on a sound technical base in which chemistry is one of the main foundation stones. I want to help build that foundation."

The new school, the first school of mines in America, opened on November 15, 1864, with an all European-trained faculty consisting of Thomas Eggleston, professor of mineralogy and metallurgy; General Francis Vinton, professor of mining; and Charles F. Chandler, professor of geology, analytical and applied chemistry, and assaying. Eggleston and Vinton were graduates of the École de Mines of Paris with good training in general chemistry. In addition to his title of professor, Chandler was appointed dean of the school. The association of these three dynamic, far-seeing, creative minds in that pioneer venture in applied science education under Chandler's forceful leadership did more to raise Columbia to the stature of a great university with worldwide influence than anything it did in the nineteenth century. The registration of 24 students was twice as great as was expected.

Chandler put his whole soul into his work. Not only did he serve as professor and dean but as janitor, plumber, carpenter, and laboratory technician. His experimentally illustrated lectures in analytical chemistry, industrial chemistry, geology, and assaying were models of excellence from the beginning. With the gift of a large quantity of minerals he immediately began the carefully planned collection of lecture illustration materials from the whole range of chemistry which in the 46 years of his teaching he built into the most unique collection of its kind in America, the Chandler Chemical Museum of Columbia University.

His reputation as an assayer spread rapidly. In 1868 he devised a new system of assay weights known thereafter as the assay ton weights, which simplified and completely revolutionized the method of evaluating the noble-metal content of ores, bullions, slags, mattes, and other metallurgical products. They are used to this day in every assay laboratory in the world. It is impossible to calculate the value of this invention to the mining and metallurgical industries over the past century.

At the end of the first year the school of mines had been such a success under Chandler's management that, after paying back $8000 it had borrowed to meet operating expenses, each of the three founders received $2000 as his salary. The registration the second year quadrupled. The trustees of the college were so impressed that they agreed to finance its development thereafter. The school's phenomenal success and the development of its department of chemistry to a stature of world recognition under Chandler's leadership for 46 years is a glowing page in the history of American chemical science.

In 1866 the New York College of Pharmacy, then in dire financial straits and almost defunct, asked Chandler, who had never heard of the institution, if he would lecture on chemistry one night each week. There would be no salary but he would have an allowance of $400 for experimental apparatus and lecture materials. After thinking it over for 24 hours Chandler decided that it was his duty to see that pharmacists had a thorough education in chemistry since "the people's lives are in their hands."

From the very day that Chandler accepted the appointment of professor of chemistry, the college of pharmacy took on new life. In his characteristic fashion he poured his soul into his lectures and laboratory courses. Registration increased at a high rate. He made it crystal clear to his students and to the pharmacists of New York and the nation that a good knowledge of chemistry was the heart and soul of their profession. "A pharmacist," said he, "without a sound knowledge of chemistry, is likely to be an unwitting fraud." For 40 years thereafter Chandler's lectures set the standard for chemical instruction in pharmaceutical education in the country.

PUBLIC HEALTH ACTIVITY

Owing to the development of alarming public health conditions in the rapidly growing city of New York, the state legislature in 1865 created the Metropolitan Board of Health with broad powers to deal with normal and emergency conditions. Where could the board find a competent scientist to make a scientific study of the sanitary problems affecting the health of the city? "The brilliant young professor of chemistry in the Columbia School of Mines is the man," said Dr. Elisha Harris, president of the board, "if we can persuade him to tackle the job without pay, as the board has no funds." Chandler accepted.

Without thought of remuneration Chandler went ahead, rendering his services without stint. He devoted special attention to the food and water supply of the city, adulteration of milk, kerosene accidents, gas factory nuisances, and general sanitation. So outstanding was his work that in the following year he was appointed chemist to the board at a salary of $2000. Most of the members of the board were physicians who had no knowledge of chemistry and were surprised that the subject had any bearing on public health. Chandler became New York's first public health chemist. This pioneer work marked the beginning of a career in the application of chemistry to the broad field of public health that set standards that were not only adopted by New York City and many other American cities, but also by cities in England, Germany, France, Switzerland, and Italy. New York's sanitary code today is essentially Chandler's sanitary code which was adopted by the Metropolitan Board of Health in 1866.

Chandler's reputation as an authority in sanitary chemistry in the following five years became worldwide. In 1872 he was invited to appear before a select committee of the House of Lords. By special act of the British parliament his standards and tests for the use of kerosene and petroleum products for public and household use were made law.

Chandler's public health activity dealt with nu-

merous topics. They ranged from the daily use of 30 gallons of carbolic acid sprinkled in the putrifying filth of the city's streets to reduce summer infant mortality and prevent cholera, to a systematic chemical study of the carcasses of cattle dying in the city of Texas cattle fever. This plunge into animal pathology in the treating of Texas cattle fever was bold for there was not at that time a department of pathology in any medical school on the continent.

Chandler's study of lead in the city water supply and its physiological effects is a pioneering classic. So great and important were Chandler's contributions to the chemistry of public health that he was appointed president of the Metropolitan Board of Health, a position which he held for two terms, from 1873 to 1883.

"So great was the board's power that it could not be tampered with by the mayor and only under extreme emergencies by the courts. It was a law unto itself as it enacted sanitary ordinances by administrative decree and could demand the assistance of the police for enforcement and protection without question." Although Chandler had unusual administrative ability, his determination to utilize his technical training in the intelligent construction and enforcement of a sound sanitary code, come what might, under the board's great power made his ten-year administration the most productive in the annals of public-health chemistry in America. His establishment of experimental laboratory research as a sound basis for theory and practice in public health and sanitation, and his invention during that period of the present-day vented, sanitary plumbing system are only two of his many contributions to better living. No public servant had greater power and used it more effectively and honestly than did this great pioneering advocate of the efficacy of applied science, especially applied chemistry, to protect and enrich the lives of his fellow men.

Chandler's reputation as a great chemistry teacher and his dramatic and successful application of chemistry and physics to the solution of the city's serious health problems brought him the offer of a position on the faculty of the New York College of Physicians and Surgeons. He already held professorships in two colleges, was chief chemist and a member of the Metropolitan Board of Health and of the Metropolitan Excise Board with heavy duties in each. His first inclination was to refuse. However, when he considered the physicians' abject ignorance of chemistry and physics, and their complete lack of appreciation of their importance as powerful and necessary tools in their profession, he saw an opportunity for fruitful pioneer work he could not resist.

In 1872 he was appointed adjunct professor of chemistry and medical jurisprudence, and four years later was advanced to head of the department. In 25 years with his forceful personality, unique skill as a teacher, and rich experience in applied chemistry, he did more to give chemistry a high place in medical education than any scientist in his generation. American medical education is deeply indebted to Chandler.

With three full-time professorships and a deanship in Columbia's affiliated professional schools, and with the strong support of the college's president, Frederick A. P. Barnard, an eminent physicist, Chandler held a commanding position in chemical education in America. That he used this position forcefully, constructively, and with consummate leadership, his accomplishments in the next 40 years attest brilliantly.

SERVICE TO GOVERNMENT

Chandler's outstanding success as a public-health chemist brought him to the attention of the National Academy of Science which had been organized in 1863 to provide scientific advice in connection with the conduct of the Civil War. Immediately following his election to membership in 1874 he was appointed by the academy's president, Joseph Henry, to investigate the condition of the manuscript of the Declaration of Independence and report what methods should be used to restore the signatures thereon and to preserve it in the future.

That was the first of a long list of important research assignments to Chandler by the academy over the 51 years of his membership. They involved research studies on problems assigned to the academy by practically every department of the national government. Among others they included sorghum sugar, starch sugar, wood preservation, food adulteration, separation of ethyl and methyl alcohol, wool scouring, dyestuffs, hog cholera, trichinosis, water supply, stream pollution, etc. His thorough and searching reports on these studies were the basis of federal legislation and departmental regulations on public health, import and export tariffs, internal revenue, custom court procedures, prevention and control of both human and livestock diseases, etc. It is doubtful if any other member in the academy's history contributed so much to the national welfare.

Probably Chandler's greatest work was his demonstration that chemistry could be put to practical use not only in medicine and public health, but in industry and trade as well. Remembering the strong advice of his teachers Heinrich Magnus in Berlin, and Baron Von Liebig in Munich, he took it upon himself as one of the prime objectives of his professional life to sell chemistry to the nation's industrialists and businessmen who had no appreciation of its vast economic potentialities. "That, along with my teaching," said Chandler to President Barnard of Columbia, "is the way I can do most to make our nation strong."

CHEMICAL JOURNALS AND ORGANIZATIONS

The importance of and urgent need for chemistry must be brought forcefully to the attention of the leaders in every phase of the country's economy. How could this best be done?

Although the first chemical society in the world, The Chemical Society of Philadelphia, was founded in

1792, American chemistry had no respectable organ. Silliman's *American Journal of Science and Arts*, founded in 1818, which for 50 years was the only medium in America for the publication of chemical papers, gave up the ghost in 1868. *The Scientific American* would not publish his papers because they were "too visionary." He would found a journal of his own.

In 1870 he and his brother William, then an instructor at Columbia, founded *The American Chemist*. It was set up for the benefit of professional chemists "who desired to publish original scientific works." Its editorial pages which glowed with Chandler's convincing enthusiasm urged American manufacturers to seek the advice and services of chemists to improve their products, lower their costs, and develop new ones. It published abstracts of papers of foreign and American journals for the purpose of making it a clearinghouse for information in both theoretical and applied chemistry. It had a corps of 28 volunteer abstractors. It also published other scientific but nonchemical information on biology, geology, mineralogy, physics, and engineering. It reflected Chandler's European education which gave him a broad international view of life. It was a high-grade scientific journal in every respect, and for the seven years of its life it courageously preached the gospel of the importance of chemistry in the development of American industry.

The editors labored long and hard to maintain high standards and keep it going. "I often felt," said Chandler, "that it was a feeble voice crying in the wilderness, and did my best to make it stronger." Although successful in its main objectives it was a financial failure from the beginning. Each year ended with a deficit which the owner-editors had to meet out of funds from their own pockets.

That was nothing new for Chandler. From the beginning of his teaching career at Columbia, when funds were not available for materials and apparatus and the salaries of additional assistants for the increasing registration in his laboratory courses, he paid for them personally. He often advanced on loan tuition and laboratory fees for promising students who could not afford them. No records are existent, but it has been estimated by his colleagues at Columbia that over the years of his active teaching service those payments amounted to many thousands of dollars for which he was not recompensed. "The cause of chemistry must go on whatever the cost," was Chandler's philosophy.

After five years of hard work and personal sacrifice it became evident that the publication of *The American Chemist* was too much for two men. If it was to survive it must have the editorial and financial support of a greater number of chemists.

In 1874 at a meeting of the chemical section of the New York Lyceum of Natural History, of which Chandler was a founder and member, the subject of a chemical centennial was discussed. This gave Chandler an opportunity to propose the organization of a chemical society. The proposal was supported by many New York chemists. Two years later at a meeting in Chandler's home on 54th Street, a committee was appointed with Chandler as chairman to draft a constitution and bylaws for an American Chemical Society. The committee issued a call for an organizational meeting to be held April 6, 1876, at the New York College of Pharmacy at the corner of Waverly Place and University Place in New York City. There in Chandler's lecture room with Chandler in the chair and 35 chemists in attendance, the American Chemical Society was born. The Columbia professor of chemistry was a happy man. A new light which he had seen from the top of the mainmast of his bold creative imagination appeared as a glowing reality on the horizon to mark the morning of a new era in American chemical science.

Arrangements were immediately made to publish the proceedings of the new society in *The American Chemist*. That was done for two years when its publication was suspended to make way for *The Journal of the American Chemical Society* which began its career in 1879. In the seven years of *The American Chemist's* life the Chandlers conceived the broad plan, breathed into it the breath of life, and laid the firm foundations on which the great American Chemical Society and its system of journals, now the pride of the scientific world, have been built. That was pioneering *in excelsis*!

INDUSTRIAL CHEMISTRY

Chandler's greatest contributions to chemical science were made in the capacity of consultant to industry. As mentioned previously, a prime objective of his professional ambition was to teach industrialists and leaders of business the practical importance of chemistry. His dynamic and constructive part in the development of practically every phase of the American chemical industry from 1864 to his death in 1925 is a glowing testimonial that he realized his ambition.

From his broad European education he considered the whole scope of chemistry as his field for operation. His consulting work covered the broad chemical aspects of water supply and its uses, milk and foods in general, coal and water gas, cane sugar, starch, glucose, iron and steel, aluminum, paints, lubricants, dye stuffs, petroleum refining, heating and lighting, ventilation, photography, caustic soda and chlorine, fermentation, municipal and factory waste disposal, vegetable and animal oils, food preservation, cosmetics, leather, textiles, and industrial poisons. In all of this work Chandler made extensive use of his profound knowledge and skill in analytical chemistry.

To solve the problems that confronted him he developed new analytical methods and new experimental apparatus, notably the assay ton weights, a universal flash-point apparatus, the Chandler photometer, the Chandler-Baumé hydrometer scale, a sludge metering device, and a flow-meter chemical-solution feeder

for water softening. The principle of the latter is embodied in some modern proportioning pumps and chemical feed-control devices.

With the increase of the use of chemistry in the great industrial development that followed the Civil War, especially in the last quarter of the nineteenth century and the first decade of the twentieth, the demand for Chandler's consulting services was so great that he generally was recognized as America's foremost industrial chemist.

In the acceptance of consulting commitments he was partial to assignments that would enable him to use his services in the public interest. While I shall not attempt to enumerate them, it is appropriate in this year (1954) to mention two examples. Seventy years ago in a detailed chemical and nutritional investigation that is a classic, he pleaded with Governor Grover Cleveland of New York, without success, to veto a bill passed by the legislature to restrict the production and sale of oleomargarine on the ground that it would deprive the public and especially the poor people of the state of a low-cost wholesome food. That vicious law, whose influence was to extend to other states, has just been removed from the New York statutes for those identical reasons.

At the turn of the century, when a proposed national pure food law drawn by his friend Dr. Harvey W. Wiley of the U. S. Department of Agriculture, was presented to the congress, Chandler, who was in sympathy with the general objectives of such a law, opposed it vigorously on the ground that it went too far and especially for the reason that it would attach a stigma to the word "chemical" which was wholly unjustified and which would be against the public interest. The numerous revisions and modifications of the law enacted in 1906, which have removed basically unsound and impractical restrictions, have proved that Chandler was right. However, the stigma which it attached to the word "chemical" was so deeply planted in the public's mind that, as he predicted, it still bedevils scientific progress in sound food production, often to the detriment of the nation's food economy. Chandler's pioneer judgment in such matters was amazingly sound.

The legal aspects of his consulting work were of great importance. As an expert witness he had no equal. In the roles of expert witness, advisor to the courts, and counselor to legislative committees of cities, states, and nation he established principles of procedure, of legal interpretation, and of judicial evaluation that are largely the basis of American chemical jurisprudence.

Selfishness was entirely absent in Chandler's philosophy of life. Anything he had in his vast storehouse of knowledge could be had for the asking if, in his judgment, it would advance the cause of chemical science. He was particularly generous if the information seeker was a young man.

It is not generally known but should be stated here that there is what appears to be reliable evidence that the basic idea in one of the earliest processes for the direct fixation of atmospheric nitrogen came from that storehouse.

In all of his extensive consulting connections Chandler never missed an opportunity to impress upon his clients the imperative need for competent scientists, particularly chemists, in their organizations, and their responsibility to support scientific education in American universities and technical schools. Funds for the construction and equipment of Havemeyer Hall which houses Columbia's large departments of chemistry and chemical engineering, for the endowment of the large Phoenix Research Fund, for the equipment of special research laboratories, and for the support of scholarships and fellowships for graduate study in chemistry and physics are striking testimonials that those pleas bore abundant fruit. As a token of Columbia's deep appreciation of his tireless and loyal services in its behalf it is particularly fitting that the nine-story building which houses the extensive and excellently equipped research laboratories of the departments of chemistry and chemical engineering was named the Chandler Chemical Laboratory.

Although so-called courses in industrial chemistry sprang up in universities and technical schools during the last two decades of the nineteenth century, most of them were little more than descriptive extensions of general and analytical chemistry by teachers who had neither experience in chemical industry nor the remotest conception of its scope or engineering requirements. Chandler's extensive consulting experience soon taught him that the conventional university courses in chemistry were decidedly inadequate to train chemists for industry, and that something would have to be done about it.

As early as 1890, as dean of Columbia's faculty of applied science, he proposed to the president and trustees of the university that a four-year curriculum, to be known as engineering chemistry or chemical engineering, leading to an appropriate engineering degree, be set up. The proposal was met by vigorous opposition from faculties of the engineering departments who characterized it as a radical innovation that was neither chemistry nor engineering, and which, if adopted, would encroach upon their time-honored precincts. Opposition meant little to Chandler when he knew he was right. After 14 years of struggle against persistent opposition his efforts were crowned with success. In 1904, just one-half century ago, the trustees of the university approved his four-year curriculum in chemical engineering leading to the degree of chemical engineer. This was the first completely integrated four-year curriculum in chemistry and engineering based on mathematics, physical science, fundamental engineering science, and economics leading to the degree of chemical engineer in America. Chandler considered it one of the crowning accomplishments of his educational career.

With the industrial expansion in the nation during the last quarter of the nineteenth century, the number

of chemists in industry increased rapidly. Chandler knew most of them personally. Most of them were employed in New York City and its vicinity and many were his former students. His concern for their professional welfare was always first in his mind.

In 1865 he, with some friends, had founded the New York University Club to promote the welfare of graduates of the world's universities who were located in New York City and vicinity. It was a great success. Chandler felt that something like that should be organized for chemists. Accordingly, in 1898 a group of chemists under his enthusiastic leadership organized The Chemists Club of New York to promote the welfare of chemists and those interested in the science and practical application of chemistry. Although it was organized to establish permanent headquarters for the chemical interests of New York City and vicinity, it soon became a national institution. Its great chemical library founded and augmented by substantial gifts from Chandler, open to professional chemists and research workers, is one of the finest in America. This unique club fathered by Chandler has done more to further the social and business interests of chemical industry and to promote the welfare of industrial chemists than any institution of its kind in the world.

Chandler was not only a great pioneer teacher and practitioner of chemistry, but also a great humanitarian. In addition he was a great chemical diplomat. As a representative and ambassador of applied science education, of professional and scientific societies, of public health societies, of American chemical industry, and of city, state, and nation, he brilliantly carried the influence of American chemistry to the educational, governmental, and trade centers of the world.

On those foundation stones, shaped and laid by Charles Frederick Chandler, the master builder, stand American chemical science, American chemical education, the American chemical and chemical engineering professions, and the great American chemical industries which make the nation strong. Such were the life accomplishments of the pioneer Columbia professor of chemistry who grew out of the New England boy who one century ago ascended to the heights that he might see the sun rise twice on Independence Day.

MARSTON TAYLOR BOGERT

DONALD PRICE
New York, N. Y.

WHEN Marston Taylor Bogert began his professional career in 1894 the United States was almost without a chemical industry. When he retired from active teaching in 1939 we probably had the largest and most diversified chemical industry in the world, even though the value of its products was less than half what it is today. The census of 1890 placed the value of chemicals and allied products made in this country at 178 million dollars. In 1939 this figure had grown to three billion seven hundred million dollars, a two thousand per cent increase. And today the value of chemicals made in this country, added by manufacture alone, amounts to well over eight billion dollars. Bogert's career spans this phenomenal growth of the chemical industry in the United States and he was one of a small group of pioneers in chemistry whose influence helped to bring it about.

EDUCATION

Bogert's paternal ancestors came to this country from Holland in 1663, the year before the British took New Amsterdam away from the Dutch. He was born in Flushing, New York, on April 18, 1868. He received his elementary education at The Flushing Institute, a well known private school. Here, in his last year, he had his first contact with the science in which he was to make his great reputation. One of the masters had a little room fitted up as a laboratory and asked if any of the boys wanted to take a preliminary course in chemistry. Bogert was one of those who accepted. The experiments were very simple and elementary but the young student was more deeply impressed than he realized at the time.

Bogert followed the family tradition by attending Columbia College from which his father and three brothers had graduated. He was not only a brilliant student but found time for an amazing number of extracurricular activities. In his freshman year he was captain of the crew that beat Harvard; he was college tennis champion; he also won honors in such diverse sports as shotputting, football, and pole vaulting; he was a top-notch ice skater and played the flute in the college orchestra. In his senior year he was elected class president and was chosen one of "the three most

deserving students in the graduating class." Besides these honors he was selected as chairman of the student body to represent them at the installation of the university's new president, Seth Low. Bogert majored in languages, ancient and modern, and was elected to Phi Beta Kappa. He received his B.A. degree from Columbia College in 1890. Professor H. H. Boyesen, a noted scholar in his day, then asked Bogert to become his assistant in the department of Germanic languages.

One of the science requirements for the B.A. degree was to attend Professor Charles F. Chandler's lectures on general chemistry. Young Bogert, who had already had some contact with elementary chemistry at school, seems to have been tremendously impressed. In any event, after a summer in Europe he declined the offer of the assistantship in languages and decided to pursue another four-year course of undergraduate study in the School of Mines at Columbia, as a major in chemistry.

There were seven or eight students in the class who majored in this subject. At this time Professor Charles Edward Colby who held the post of adjunct professor of organic chemistry was taken ill and had to give up teaching. So there was no one available to teach organic chemistry to the class. Chandler was so busy with his academic and civic duties that he did not have a free minute, so he suggested that the students teach themselves. And this they did successfully. So we have the unique situation of one of the most distinguished American organic chemists, an internationally recognized figure, who never had a lesson in organic chemistry from a professor. In his chosen field he was entirely self-taught. Bogert graduated from the School of Mines with the degree of Ph.B. in 1894.

PROFESSOR, RESEARCHER, WRITER

Chandler recognized Bogert's ability as a student while at the School of Mines, and because of Colby's illness asked Bogert to take over the instruction in organic chemistry upon his graduation, first as assistant and tutor from 1894 to 1897, then as instructor from 1897 to 1901, adjunct professor from 1901 to 1904, and finally as the first full professor of organic chemistry at Columbia in 1904. This post he held for 35 years until his retirement in 1939.

Bogert continued to work actively long after he became emeritus professor. In fact he carried on many of his activities up until a few months before his death. Accordingly, his professional career covers more than half a century. During this time Bogert published more than 500 papers approximately half of which were original scientific contributions. The amount of scientific work involved is staggering. Most of his papers were published in collaboration with candidates for the Ph.D. degree. Assuming that on the average such a student works two years on his thesis, Bogert's scientific papers represent 500 man-years.

Bogert's interests ranged over almost the whole of

Marston Taylor Bogert

synthetic organic chemistry, although two fields in particular occupied his attention, especially during the earlier years of his career. These were the field of quinazolines and that of the thiazoles. He published 44 papers on quinazolines and 27 on thiazoles. Other fields in which he worked and published as many as a dozen papers are too numerous to refer to here. His favorite subjects were dyestuffs, pharmaceuticals, and particularly the essential oils. For many years he taught three advanced courses, if as many as seven students registered for them, one on dyestuffs, the second on drugs, and the third on perfumes. Bogert almost always wrote up the work of his Ph.D. students for publication in the scientific journals and invariably did a beautiful job of presentation, especially where he was confronted with the difficult task of condensing a large mass of data into limited space and still preserving clearness. His gift for languages stood him in good stead in this connection. Bogert's miscellaneous papers cover a wide range of subjects from conservation of natural resources to pleas for international cooperation. However, chemistry was his great love, and somehow he never failed in all his writings to get in a "plug" for chemistry and for the chemist.

Bogert was an excellent teacher whose systematic mental processes and remarkable memory gave him the ability to present the wonderful classification and interrelations of organic compounds in such a way as to inspire his students. He loved seminar work and liked to give informal quizzes that he enjoyed much more than his students did. He wrote on the blackboard in a clear precise hand, holding the chalk in one hand and an eraser in the other. As he talked he wrote formulas on the blackboard and often erased them so fast that it was all his poor students could do to get them down into their notes.

His flair for extracurricular accomplishments carried through from his undergraduate days into his later life. It is hard to understand how one man could do so many things so well, except that he was a prodigious worker. His usual work schedule ran from 10 to 14 hours a day. He rarely went out to lunch but had some sandwiches and fruit, of which he was very fond, in his office. If one of his students happened to visit him during the lunch hour he would be likely to find the professor's lunch laid out neatly on a napkin on his desk with a bunch of grapes in a large porcelain evaporating dish. With a twinkle in his eye, the professor would generally invite him to have some fruit.

PROFESSIONAL ACTIVITIES

Versatility was Bogert's undoing. People soon discovered it and also found out that he was a hard worker. Accordingly, he was swamped with positions on committees, advisory boards, congresses, societies, editorial boards, and every other conceivable scientific activity. Whenever anything needed to be done in the field of chemistry people said, "Let's try to get Bogert." But he took all these activities in his stride and enjoyed them thoroughly. He believed that a real chemist must be ready to give a substantial proportion of his time to advancing his profession. In my opinion the reason that the profession of chemistry ranks below the older professions, such as law and medicine, in the public mind is because so few of us follow the example set by Bogert.

Bogert joined the American Chemical Society upon his graduation from the School of Mines in 1894, and served the Society in many capacities. In his first lecture of the school year he always urged his students to join also. In 1907 and again in 1908 he was elected president of the Society and perhaps he made his greatest contribution to chemistry during these two years. At this time the industrial chemists were threatening to split away from the parent organization and form a society of their own. Bogert, who was a staunch believer in close contacts between men in all fields of science, met this threat by conceiving and carrying out the plan which has resulted in the present structure of the A. C. S. The society was divided into sections according to the interests of its members. The *Journal of Industrial and Engineering Chemistry* was established and placed upon such a firm foundation that it became an outstanding success. The first issue of this journal appeared on January 1, 1909.

Another professional activity with which Bogert associated himself was the formation of the Chemists' Club of New York. In the late nineties a small group of New York chemists felt the need for club rooms of their own in which to hold A. C. S. meetings and other gatherings, but they were opposed by another group who said it would not work, "Chemists are too poorly paid and too few in numbers to support the cost," they said. The statement about pay was very likely true. But Charles F. McKenna, William McMurtrie, Marston Taylor Bogert, and a few others believed it could be done. A committee was organized with Charles F. Chandler as chairman and Bogert as secretary, and the club was organized on November 29, 1898, with 154 charter members. Its headquarters were in what had been the old Mendelssohn Glee Club, 108 West 55th Street. In 1909 The Chemists' Club Building Committee was organized, again with Bogert as a member. Land was purchased on East 41st Street where the club erected its own building and where it still stands. The new club was opened on St. Patrick's Day, 1911, and its 1000 members moved in. Bogert served as the club's first secretary and as its president in 1908. He survived to be the club's only living charter member. The large front dining room of the club where Bogert presided at so many dinner meetings over the years has recently been named The Bogert Room in his honor.

The scientific societies in which Professor Bogert was active are far too numerous to list here. I would refer my hearers to "Who's Who" or to "American Men of Science." A few, however, deserve especial mention. In 1908 Bogert's distant relative, President Theodore Roosevelt, invited him to be a member of the White House Conference on Conservation of Natural Resources. At a second such conference at which the governors of all the states and territories were present, he gave addresses in all of the four divisions—water, land, forests, and minerals—and pointed out how chemistry could aid conservation. At the Baltimore Meeting of The American Chemical Society in 1908 he gave a paper entitled, "The function of chemistry in the conservation of our natural resources." This was later published in the *Journal of the American Chemical Society* (**31**, 125–54 (1909)). Bogert called attention to the criminal waste of our natural resources and how chemistry could help to prevent it. Even today some of our public officials and industrialists would do well to read this paper.

PUBLIC SERVICE

Bogert served his country well in two wars. Almost a year before the United States entered World War I he was called to Washington as a member of the National Academy of Sciences, to organize the chemistry committee of the National Research Council, and became its first chairman. He stayed in Washington and was active in several departments, joined the army as a lieutenent colonel where he was placed in charge of the Chemical Service Section of the National Army. Soon, owing to his efforts, this section was united with gas warfare becoming the Chemical Warfare Service. He was promoted to the grade of colonel and put in charge of the Relations Section; he acted as a member of the Executive Committee of Headquarters Staff as well as of many other committees. Bogert was very proud of his military service and said very frankly that he preferred his title of colonel to any of his other titles. Many of his friends and associates always

called him colonel. During World War II, Bogert was again called upon by the government and served on a number of technical committees connected with the war effort.

Needless to say Bogert received many honors during his career, beginning with the award of the Nichols Medal of the American Chemical Society in 1905. In 1912 he was elected president of the Society of Chemical Industry of Great Britain. At its 25th anniversary, Clark University awarded him the Honorary Degree of LL.D. and his own Alma Mater gave him recognition at its sesquicentennial in 1929, with the award of the Doctor of Science degree. In 1938 he was awarded the Priestley Medal as well as the Gold Medal of the American Institute of Chemists. Columbia awarded him the Egleston Medal in 1939, and the Chandler Medal in 1949.

In 1927–28 Bogert decided to take a long overdue sabbatical leave and planned a pleasant sojourn in Europe with Mrs. Bogert. However, when President Butler learned of his intentions he called him in and persuaded him to go to Czechoslovakia as representative of the Carnegie Foundation for Peace, and he became the first visiting professor of international relations to that country. He was required to lecture at the Charles University in Prague which was founded 150 years before Columbus discovered America. Bogert told me that preparing these lectures almost spoiled his fun. While in Czechoslovakia he was awarded degrees by the Charles University and by the University of Bratislava. He also was made a commander of the Order of The White Lion of Czechoslovakia by President Masaryk.

CONCLUSION

Marston Taylor Bogert was one of the great personalities of American science. He was an excellent lecturer and an unsurpassed toastmaster, so was constantly in demand as a chairman for meetings and conferences as well as for the presentation of honors to distinguished fellow scientists. Bogert was a strong believer in recognition for scientific accomplishment. He derived great pleasure and satisfaction from the honors he himself received and delighted in honoring his fellow scientists. An important function that he rarely if ever missed was the Perkin Medal Dinner, where as senior past president of the Society of Chemical Industry, in his famous mauve tie, he presented the Perkin Medal. He was a familiar figure at meetings of the American Chemical Society which he attended regularly. No matter what section he happened to be in, he usually had comments to make on one or more of the papers. These were never critical but served to bring out some point that otherwise might have been missed. Bogert had a keen sense of humor and thoroughly enjoyed a joke even if it was at his own expense. His students will remember him best as dressed in the blue or maroon velvet smoking jacket he wore in his classrooms and seminars, although he never smoked.

Throughout his entire career Bogert demonstrated his firm belief in international cooperation between scientists, and free exchange of scientific information. He always took an active part in the International Union of Pure and Applied Chemistry where his ability as a linguist stood him in good stead. Those who were present at the dinner given to the delegates at the meeting of the International Union in 1926 will remember how graciously he called upon the speaker from each country, addressing him easily in French, German, or English as the occasion required. Bogert was elected president of the International Union at its tenth meeting in Rome in 1938, but during the war years the Union ceased to function. After the war, largely owing to Bogert's efforts, the Union was revived and he was again elected president.

In 1893 Bogert married Charlotte E. Hoogland and few men have enjoyed a happier family life than he. Mrs. Bogert and their two daughters, the present Mrs. Frank B. Tallman and Mrs. F. K. Huber, were often called upon to entertain colleagues or students. Bogert followed the old German custom of having his students gather together at his house at least once every year where there was generally some good music and everything was talked about except chemistry. For many years the Bogerts spent their summers at their summer home at Belgarde Lakes, Maine, where they entertained many friends on week ends and where the colonel, as he loved to be called, could indulge in his favorite pastimes of fishing and playing tennis. However, his summers were by no means devoted entirely to recreation. Several heavy suitcases loaded with manuscripts and scientific data were always taken along and his mornings were devoted to writing up the accumulated experimental results of the previous academic year.

Scientists of outstanding ability may contribute to their chosen fields in many different ways. Some do so as great discoverers, others as great teachers, and still others as writers. Each one performs a valuable service in his own way. If we survey the career of Marston Taylor Bogert, I believe we can only come to the conclusion that, notwithstanding his extensive researches, he made his greatest contribution to science as an interpreter of chemistry. With his great gifts of clarity and persuasion he brought the value and importance of chemistry before public officials, military men, and industrialists who otherwise would never have grasped them. During his lifetime chemistry grew from very humble beginnings to the vast proportions of the present day, and Marston Taylor Bogert was one of those who played a major role in bringing this about. For the good of our science let us hope that we have more men like him.

HENRY CLAPP SHERMAN

EDWARD C. KENDALL
Princeton University, Princeton, New Jersey

FIFTY years ago, that is in September, 1904, a freshman wearing a small cap with a green button first came to the campus of Columbia University. He observed that the administration building was not complete. The floor, level with the upper campus, was covered with a temporary roof, and the powerhouse stack extended upward exposed on all sides. The exterior of Havemeyer Hall, the chemistry building, appeared much as it does today.

As the days and weeks passed the freshman went to the lectures of Professor Chandler and came to know the other members of the faculty who taught the incoming class of future chemists. However, there were other members of that distinguished faculty who taught the upper-classmen. Each morning Professor Bogert walked with firm step into Havemeyer Hall and climbed to the second floor. Professor Miller was a tall man with long deliberate stride. His close-mouthed assistant, Dr. Jouet, was a medium-sized gentleman of French descent.

Each day Drs. Metzger, Bean, Hall, Morgan, and many others were swallowed by the wide doors of the chemistry building. A certain aura of mystery surrounded these men, but for the freshman Dr. H. C. Sherman became of special interest. He was a man of medium height and weight. He walked with a quick step and deliberate manner, anxious to reach his destination. He created an impression of definiteness combined with confidence. His quiet, assured manner suggested that he was in his forties; he was 29 years old. Never once did one see Dr. Sherman slap a friend on the back and extend greetings in a hearty way. His voice was never raised in anger or mirth.

Although H. C. Sherman was unusually quiet he was not in any sense what is now known as a "stuffed shirt." If you saw him in conversation it became obvious that he was affable and courteous. The fact that he was quiet made you want to see more of him. The young freshman looked forward to the day when he would know more about Dr. Sherman, but he also wanted to understand what force drew this man to Havemeyer Hall; what were the problems that absorbed his attentions; what were the results of his efforts.

Fifty years have now passed. The administration building is still unfinished. The temporary roof and stack remain as they were in 1904. But other things have changed. No member of the faculty of 1904 now enters Havemeyer Hall. Their places have been filled by other able scientists. New chapters are being written, but the memory of the men who first occupied Havemeyer Hall remains with us.

It is a pleasure and an honor for the freshman who entered Columbia in September, 1904, to express an appreciation of one of the pioneers in chemistry at Columbia.

Henry Clapp Sherman was born on a farm at Ash Grove, Virginia, October 16, 1875. The ancestors of both parents came from Britain. In 1893, at the age of 18, Sherman received the degree of Bachelor of Science from Maryland Agricultural College (now the University of Maryland). For two years he worked as an assistant in the laboratory of the State Chemist of Maryland. He found time to publish a paper on "Determination of nitrogen in fertilizers containing nitrates." The following two years he was a fellow at Columbia University and received the degree of Doctor of Philosophy in 1897, at the age of 22. The title of his thesis was: "The Insoluble Carbohydrates of Wheat (*Triticum Vulgare*)."

FOOD ANALYSIS

The year 1898 was spent in the laboratory of W. O. Atwater and in 1899 Sherman returned to Columbia as a member of the department of chemistry under Professor Miller who was in charge of analytical chemistry. Although proximate organic analysis of oils, fats, and food products had been carried on in the analytical laboratory ever since the School of Mines was started at Columbia, it was not until 1899 that a course in this branch of quantitative analysis was made available to the students. H. C. Sherman was given the opportunity to develop this new field of research.

This was a fortunate decision. In 1899 no one could foresee that the next 50 years would witness the discovery of the hormones, vitamins, and amino acids essential for growth and well being. Neither could the trustees of Columbia know that in H. C. Sherman they had chosen a man who, as a pioneer in the new science of nutrition, would reach the highest levels of success.

But now we can look backward and see that the opportunity waited for the man, and we also can see that the man approached his future well equipped with a most essential tool. That tool was a full appreciation of the power of quantitative analysis.

THE "QUANTITATIVE" INFLUENCE

I believe that during the years immediately following 1899, H. C. Sherman was most interested in methods of quantitative organic analysis. The words "determination of" or "determined" occur 12 times in the titles of the first 51 papers Sherman published.

Later methods of analysis became the means to an end, but throughout his scientific career the word "quantitative" was a key which he used to unlock barriers to success.

In 1905 H. C. Sherman published his first textbook: "Methods of Organic Analysis." Recognition of his contributions came rapidly, and promotion through the several steps to full professor followed within a few years. The enrollment in his courses increased, particularly at summer sessions. Graduate and post-graduate students were attracted to his laboratory and an uninterrupted flow of papers came from his pen.

I was a graduate student in Sherman's laboratory during the years 1909–10. Sherman's first paper on enzymes was based on the subject of my thesis, the title of which was, "A Quantitative Study of Pancreatic Amylase."

Ever since that thesis was written it has been my belief that the word "quantitative" in the title was chosen by myself. However, when I began to prepare the manuscript for this paper doubts arose in my mind. It now seems probable that directly or indirectly Professor Sherman was responsible for the selection of that word. At any rate, I clearly can remember his suggestions concerning the arrangement of the subject matter and his insistence that the experimental part contain all the information needed to repeat the results.

These facts are mentioned to emphasize the high quality of the association between student and teacher. As Lafayette B. Mendel remarked in 1934 when the Nichols medal was awarded to Sherman: "The potent indirect influence of the analytical period has further manifested itself in the work of Sherman's many research pupils—all endowed with habits of patient endeavor and meticulous procedure disclosed in their later scientific undertakings."

PIONEERING RESEARCH

Through associates and students Sherman continued to study the chemical properties and activity of enzymes for the following 25 years. Many notable contributions in this important field came from his laboratory. Throughout this work, progress was made only through creative genius. No precedents could be followed, for in these researches Sherman and his associates were pioneers.

In 1918 work was published concerning the efficiency of different proteins in human nutrition. This aspect of nutrition absorbed more and more of his attention for the remainder of his career. His mastery of analytical chemistry, his interest in new and improved methods, and his critical judgment formed the basis for the advances made in this field.

Another problem was investigated from the earliest years for almost all of his active life. This had to do with the quantities required for a balanced mineral metabolism—calcium, phosphorus, and iron, with less attention to nitrogen and sulfur.

Closely related to these subjects was a study of the span of life as it is influenced by dietary intake. To some, these topics sound prosaic and uninteresting; they involve countless analyses and decades of time. But Sherman pursued these investigations with ever increasing enthusiasm and satisfaction.

This work involved much more than chemical analysis. The problems were dynamic in nature, for now he was using the live rat as a criterion. Patience and persistence were required to overcome the problems that arose. The investigation was begun before any vitamins had been isolated. Not all of the amino acids had been discovered, and other dietary essentials were known only by the effect of their deficiency.

It was possible to make progress, however, and in 1920 came the report of his first work with the vitamins. In this field Sherman developed methods of assay for vitamin A, thiamine, ascorbic acid, and riboflavin. At that time they were known only as A, B^1, C, and B^2. I shall mention a few details to illustrate the kind of question that had to be answered.

(1) What kind of rat should be used? He selected a strain previously used in Mendel's laboratory.

(2) Should the rats be purchased on the market or raised in the laboratory? He decided to raise all rats used. No outside rat could be brought into the laboratory.

(3) Should the cages be sterilized? They were sterilized with steam.

There were other details concerning the preparation of food and the daily routine to be followed. In the case of guinea pigs and vitamin C, the diet finally selected by Sherman and La Mer was prepared with milk powder spread one-half inch thick over a pan and heated at 110° for two hours. The milk powder constituted 30 per cent of the diet. Fifty-nine per cent was a mixture of oats and bran, one to one by volume. Ten per cent was butterfat and one per cent was sodium chloride. Special diets and techniques were worked out for the other vitamins.

Sherman's work in the field of vitamins received high praise from C. A. Browne at the presentation of the Nichols Medal in 1934 when he said:

> It was a most fortunate occurrence for the recent science of vitamin research that it had a cautious man like Sherman, with his insistence upon the value of quantitative relations, to help keep this newly launched bark of discovery upon an even keel. So large a quantity of the literature on vitamins is valueless and there was needed a critically minded investigator who had the patience and capacity to review all that was published on the subject and to eliminate what was worthless. Henry C. Sherman might almost be called the codifier of vitamin research.

I have mentioned no less than five divisions of Sherman's life work: a study of methods of organic analysis; basal requirements of minerals, especially calcium and phosphorus; the determination of the activity and properties of enzymes; the quantitative measure of response to vitamins; and the influence of dietary intake on the life span.

It can be seen that as the years passed there was a progression in his viewpoint and interest. By the use

of newer methods which he developed, he visualized the opportunity to make important contributions to the science of nutrition. The methods involved large numbers of animals, a loyal staff of technicians, an able group of associates and students, large sums of money, and most important of all, years of patient planning and hard work. But the results were rewarding; they furnished the basis for far-reaching conclusions. He summarized experimental results concerning the best levels of intake of various nutrients in the statement:

> Of fuel food it is true that the optional intake is close to the actual need; of protein and some of the mineral elements, we regard a margin of something of the order of 50 per cent as a desirable sort of insurance. But now we find that of some of the vitamins the desirable margin is of a higher order and the resulting benefits seem to be not merely of the nature of insurance or the correction of some slight and hidden deficiency, but rather a constructive advance.

Near the close of his active service he expressed confidence in the future as follows:

> Thus our forward view in nutrition is one of rapidly and widely expanding opportunity. A generation ago the broader-minded workers in the chemistry of food and nutrition could see that fuller use of the research methods of organic chemistry might be expected to bring to light substances previously unknown, which expectation the vitamin discoveries have abundantly justified. At the same time, two other lines of advance—the use of physical chemistry both for viewpoints and implementation, and the development of the laboratory animal colony into an instrument of precision of a new kind—have together brought results of a more constructive nature than any scientist of a generation ago could have expected.
>
> And so, the nutritionally minded chemist may now become not only a policeman or repair man to prevent or correct malnutrition but he can also work more constructively as an architect of the higher health.
>
> The nutritional chemistry of today gives us, as soon as enough of us will, the power to take a larger share in the shaping of human life history than science hitherto believed possible.

Through the long-time experiments which led him to such a conclusion, Sherman has established a new concept—namely, that the internal chemistry of the animal organism is not fixed and inflexible. Man can influence his internal environment, improve life expectancy, and extend the prime of life—that is, the years of usefulness to society.

To make that announcement was, in itself, a reward and source of satisfaction to Sherman. But many organizations, institutions, and societies took delight in honoring him. I shall not recite the long list of honorary degrees, awards, and medals which he received. He was a member of the Food and Nutrition Board of the National Research Council and of many other national and international committees dealing with food and nutrition. He was elected to membership in the National Academy of Sciences in 1933.

Sherman's publications include over 200 papers which deal with original research; The American Chemical Society Monograph on Vitamin A; a series of textbooks; and numerous popular lectures.

SHERMAN THE MAN

I have tried to summarize Sherman's principal contributions. For this I have received indispensable help from three of his former associates, C. G. King, J. M. Nelson, and A. W. Thomas. Much of what I shall say concerning H. C. Sherman the man also came from the same sources.

Publication of more than 200 carefully written scientific papers clearly shows that Sherman was both diligent and persistent. But scientific papers do not reflect his genial capacity for friendship, his deep understanding of human nature, his lack of malice and intrigue, his sense of humor, his modesty and generosity, in short, his kindly spirit which endeared him to his students and associates.

To all visitors Sherman was an attentive listener. If the occasion were an exchange of stories one would receive as much as he gave. If advice were sought the asker would have full opportunity to state his problem. The answer would reveal understanding and sound judgment. If an emergency arose, a student afflicted with a sudden abdominal pain, for example, the welfare of the student came above all else. On one such occasion Sherman ordered a taxi, accompanied the student to his room, called a physician, and waited until he arrived.

Sherman's sense of humor was of a rare quality. A lively twinkle would appear in his eyes, his voice assumed a subdued tone—and at the right moment he would chuckle in a restrained but highly infectious manner.

In a conversation in 1924, he told me that he had been appointed to be Mitchell professor of chemistry by the trustees of Columbia University. This was an honorary appointment to the most distinguished position in the department of chemistry. Sherman deeply appreciated it; however, the last half of the official notification could be construed as an anticlimax. It stimulated his sense of humor and we had a good laugh over it. The appointment was "from July 1, 1924, during the pleasure of the trustees, without change of salary."

Sherman never engaged in polemics, even when he was clearly in the right. A difference of opinion concerning the nature of enzymes arose between Professor Sherman and Professor Willstäter. The former had published excellent evidence that highly purified digestive enzymes were protein in nature. Willstäter gave a public lecture during which he expressed the conviction that these enzymes were not proteins. Although Sherman was in the audience he did not raise the argument at the time or later. We now know that he was right.

It was indeed a pleasure to attend a formal lecture given by Sherman. His diction was well chosen and carried the hallmark of thoughtful effort. When one of his students remarked that he had spent a lot of time writing his thesis, Sherman replied that it was

not uncommon for him to rewrite a manuscript as many times as there were words on a page.

Research projects, reports, and manuscripts did not occupy all of Sherman's time and energy. It is probable that, in the early years, he spent much of his time as a teacher for financial reasons. However, he enjoyed contact with young people, and teaching was a source of great satisfaction to him. His influence has been carried throughout the scientific world through his students.

What force drew H. C. Sherman to Havemeyer Hall? I believe that in 1899 the force was composed largely of loyalty. He was loyal to the trustees of Columbia University and to the other members in the department of chemistry. Soon, however, loyalty was strengthened with devotion. Passing of the years created in him a desire to be of service. Finally the force was further augmented. The quality of his effort is in keeping with the statement: He consecrated his life to teaching and research in the science of nutrition.

His life will remain as an example of a cultured gentleman, a pioneer to guide those engaged in research, a teacher for those who teach, and an unselfish worker devoted to his fellow man.

JOHN MAURICE NELSON

ROGER M. HERRIOTT
Johns Hopkins University, Baltimore, Maryland

It is a great pleasure for me to join with other members of the American Chemical Society in this Bicentennial Celebration of the founding of Columbia University, and in paying honor to four of their distinguished professors and pioneers of chemistry. Columbia has a long tradition of leadership in teaching and research in chemistry, and these biographical sketches will contain many important milestones which these four men have established. I am particularly happy for this opportunity to talk about Professor Nelson for my debt to him is, like that of so many of his students, very great. His patient but firm guidance during those formative years is only now being fully appreciated as we in turn shoulder the responsibility for guiding graduate students.

It is unfortunate that restrictions of time and space will not permit a complete review of Professor Nelson's research activities. Many deserving contributions will have to be passed over or at best merely noted. That it should be necessary to apologize for deleting some studies from the discussion is an indication of the abundance of good research in which he has participated.

John M. Nelson

EARLY YEARS

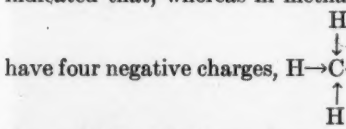
John Nelson was born in 1876 near West Point, Nebraska, of emigrant Scandinavian parents. His formal education included the usual periods at a country school, high school, and four years at the Nebraska State University. At the university young Nelson came into contact with John White, professor of inorganic and analytical chemistry, who had just returned from a leave of absence spent in Ostwald's

laboratory in Germany. From Professor White, Nelson was to get his introduction to physical chemistry, entirely on an informal level for there was no course offered in the subject. He also was to learn with interest about the newer ideas developing from research. Nelson's selection of Columbia University to pursue his graduate training was probably influenced by the fact that his student-friend at Nebbraska, Hal T. Beans, had preceded him to Columbia by a year or two. Professor Nelson's doctorate work was carried out under the direction of Professor Bogert (see page 506).

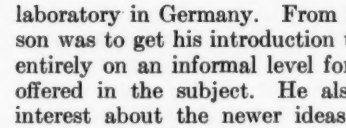
His thesis work concerned the structure of ethyl *p*-iminosuccinylosuccinate and its possible relation to indigo. In this study he found that in contrast to the para derivative, fusion of meta-phenylendiamine with potassium hydroxide gave products resembling indigo. He later found with Falk that geometric isomers like these often exhibit differences in color, and they suggested that one of the two acetyl indigo whites was probably optically inactive because of internal compensation (*meso*), whereas the other was a racemic mixture.

ELECTRONIC THEORY OF VALENCE

Nelson's first major contribution to theoretical chemistry came soon after he received his doctorate, in 1907. In this year J. J. Thomson published his classical "Corpuscular Theory of Matter," in which he suggested that chemical reactions resulted from certain atoms giving up electrons, thereby acquiring a positive charge, while others accepted the electrons and became negative. This treatise interested Nelson who, with his friend K. George Falk, extended Thomson's ideas to organic structures. In the first of a series of papers Falk and Nelson proposed an electronic theory of valence in which they suggested that the direction the electron moves in a reaction would depend on the relative position of the reacting elements in the periodic table. Thus, in the horizontal rows, the higher atomic weights would be expected to be negative to the lower-weight elements. They also diagrammed the direction of the electron shift through the use of arrows in place of the usual bond symbols. Falk and Nelson recognized that elements such as carbon, sulfur, the halogens, etc., would either accept or give up electrons depending on the conditions and the nature of the combining atom. On the basis of this concept they offered an explanation for the reaction properties of molecules that had not been understood, and offered new interpretations of old systems. Thus, they indicated that, whereas in methane the carbon would



have four negative charges, H→C←H, from the attraction of the electrons from the four hydrogens, ethane would have one carbon with four negative charges and the other with only a net charge of two,



H→C+→C←H, suggesting that one carbon of ethane would be more reactive than the other. This concept also permitted them to offer an explanation for the fact that the properties of saturated dicarboxylic acids of uneven-numbered carbon atoms resemble one another more than they do the members of the even-numbered series. In the uneven series the distribution of charges would be symmetrical, whereas in the even-numbered series they would not.

The authors also explained isomers of unsaturated or double-bonded structures and aldoximes on the basis of their directed valence concept. Their interest and application was not confined to the organic compounds. Properties of the Werner-type structures, such as cobaltamine nitrites, also were discussed.

This work next led Nelson, Beans, and Falk, in 1913, to make the generalization that the process of oxidation involves the loss of electrons, while reduction requires their uptake. This is accepted the world over as an established concept, but few realize that Nelson was the first or perhaps one of the earliest to recognize and enunciate it.

These publications clearly demonstrated to the chemical profession that in this young instructor Columbia had a stimulating investigator who could be counted on to influence the trend of chemical thought.

THE QUINHYDRONE ELECTRODE

Nelson next became interested in the quinhydrone electrode. He and Granger examined the electrical potential developed by this system, and then determined how it varied with hydrogen-ion concentration. This system conformed so closely to van't Hoff's law that it was quickly adopted for use in making pH measurements. Perhaps more important, the general subject of potentiometric studies of oxidation-reduction reactions was stimulated greatly by this very careful work.

ENZYMES

Nelson entered the enzyme field very early in his career, and he and his students directed their energy toward unraveling the secrets of this fascinating class of substances. In the earlier years the European investigators were the accepted leaders in the field. Most of them were agreed on the concept that enzymes were organic catalysts, but since no enzyme had been isolated, the exact chemical nature remained a matter for speculation, and much of this was far from the mark. It must have been with keen satisfaction that Nelson followed the progress of his former student John H. Northrop, as the latter performed the rigorous experiments to prove the protein nature of proteolytic enzymes which he and his associates isolated in crystalline form. Although Northrop's thesis work under Nelson had dealt with the phosphorus linkage in starch

grains, it may not be amiss to suggest that his interest in enzymes probably had its roots in Nelson's laboratory, for enzyme problems occupied a large part of the laboratory discussions at that time as well as later.

INVERTASE

Although Nelson held to a general plan of enzyme study, this did not prevent him from appreciating the value of certain side issues. Often tangential problems developed which were of sufficient importance to warrant a temporary digression. Such a problem was that found by Nelson and Fales, who, in the process of studying the effect of pH on invertase action, uncovered the basic observation that was to occupy many physical chemists for years to come. They found that addition of sodium chloride to acid solutions resulted in an apparent increase in the hydrogen-ion concentration. This was proven by direct electromotive-force measurements, as well as by the rates of hydrolysis of cane-sugar solutions. This was the first well documented case of the salt effect which led eventually to G. N. Lewis' concept of ion "activity" of strong electrolytes. Dr. Fales later became professor of chemistry at Columbia.

Among the significant studies on invertase were the early ones by Nelson and his students Griffin and later Hitchcock, who found that invertase adsorbed on alumina or charcoal retained its full activity. This surprising result suggested that adsorption of the enzyme does not block free diffusion of the substrate to the catalytic center. It also had some interesting implications regarding homogeneous versus heterogeneous catalysis.

KINETICS OF INVERTASE ACTION

In his kinetic studies of invertase action Nelson, assisted by Landt, Bloomfield, Freeman, Post, and Anderson, understood competitive inhibition of enzymes long before the present-day subject was developed. He recognized such inhibitors, as had others, as substrates of slightly different structure or as products of hydrolysis. In some very interesting studies he showed that the various mutameric forms of glucose and fructose had quite different inhibitory action on the enzymatic hydrolysis of sucrose. Invertases from different sources responded quite differently to these inhibiting structures. Thus, Nelson and Sottery made the interesting observation that the action of honey invertase on sucrose is not inhibited, but accelerated, by alpha- or beta-glucose.

Up to the time Nelson began his studies of invertase there was no general equation which described the course of this enzyme's action. Kinetic studies in this field were advanced materially, therefore, when Nelson and Hitchcock developed an empirical formula which described precisely the hydrolysis curve over a range of 90 per cent of the entire reaction. Among other things this formula has proved useful to workers in the field for the detection of abnormal invertase preparations.

Perhaps one of Nelson's most important contributions to the kinetic studies came when he and Schubert demonstrated the importance of water concentration in the rate of hydrolysis of sucrose. The rate of hydrolysis increases as the sucrose concentration rises until a maximum is reached at about five per cent substrate, after which the rate falls off instead of remaining constant. It had been generally supposed that the water concentration was so great that it was not essentially changed by a rise in the substrate concentration. Nelson and Schubert found that by holding the sugar concentration constant and reducing the water concentration by other means, such as the addition of any of several miscible organic solvents, they produced the same result as did raising the sucrose concentration. This suggested that the effective water concentration is considerably lower than the previously assumed value.

Very few studies have compared the intracellular to extracellular action of enzymes except for incidental measurements preliminary to isolation work. Here again Nelson and his associates, Wilkes and Mrs. Palmer, pioneered in an important manner. They studied the characteristics of invertase in the living yeast cell and in solutions from yeast autolysates. It was observed that the two systems exhibited identical pH-activity maxima, responded similarly to varying substrate and water concentrations, and were indistinguishable when examined with the aid of the very sensitive Nelson-Hitchcock equation. This showed that the enzyme as a part of the cell is free to act in its characteristic manner. So comparable were the two systems that the conclusion was inescapable that the invertase in the yeast cell is near the surface.

PURIFICATION AND THE CHEMICAL NATURE OF INVERTASE

Two of the major problems facing all students of enzymes have concerned the chemical nature of these catalysts and how they exert their characteristic action. Ever since his original paper with Born, Nelson has been keenly interested in the nature of invertase. This, of course, led to purification studies. Through the years many investigators attempted the purification of this enzyme. They succeeded in obtaining very active preparations which, however, contained virtually no weighable material.

Under Nelson's tutelage Lutz took hold of the problem, and with the aid of Stanley Lewis they put hundreds of pounds of yeast through an involved purification process. Ultimately they obtained the purest and most active invertase preparation up to that time. Although many properties indicated that the enzyme was protein in nature, it was appreciably soluble in saturated ammonium sulfate, which is certainly an unusual property for a protein.

About this same time others of Nelson's students were examining the nature of invertase by less direct methods. In one of these the protein nature of the enzyme was tested by applying to solutions of in-

activated enzyme the procedures for reversing protein denaturation. Reactivation of heat, acid, or alkali inactivated invertase solutions was obtained following treatment designed to reverse denaturation; this gave support to the hypothesis of the protein nature of this enzyme. The protein hypothesis received additional support from the immunological studies of Nelson and Mrs. Schubert.

COPPER PROTEINS

Let us now examine another subject to which Nelson devoted considerable thought and research work. This is the field of copper proteins of which the enzyme tyrosinase is the conspicuous example he chose to study. The mechanism of action of the enzyme which in nature leads to "browning" in exposed plant tissues, or pigmentation in animals, was studied in considerable detail by Nelson and Dawson. They developed a titrimetric method for evaluating the enzymatic action in its oxidation of catechol, and as a result of these studies it was demonstrated that one of the intermediate products of reaction is benzoquinone. This important finding was followed by Nelson and Wagreich's observation that during the disappearance of *o*-benzoquinone a new substance was formed, behaving toward the enzyme as would catechol. This compound appeared to be 4-hydroxybenzoquinone. They suggested that it is this material which polymerizes to the highly colored humic acid-like pigments.

Another important step in the mechanism of the over-all reaction was established by Nelson and Robinson, who found that in the presence of ascorbic acid the tyrosine concentration remains essentially unchanged. This suggested that the ascorbic acid was reducing the oxidized tyrosine as fast as it was formed, and that only after the ascorbic acid was used up was there a drop in tyrosine level. Purification of the enzyme tyrosinase from the common mushroom was undertaken by Dalton and Nelson. They succeeded in obtaining a crystalline copper protein, but the crystals became insoluble and inactive on standing. Although the ratio of enzymatic action on catechol to that on cresol of this purified material changed to a 10:1 ratio during purification, it was not possible to separate the two activities further. It was suggested, therefore, that the enzyme tyrosinase has two different active sites. This work on the phenol oxidases is being vigorously pursued by Nelson's successor Charles Dawson.

PLANT RESPIRATION

In the field of plant respiration Nelson also has made notable contributions. With his students Baker, Walter, and Rudkin he has been interested in the terminal oxidation of phenolic compounds. They were able from their experimental results to exclude the possibility that cytochrome oxidase plays a prominent role as a terminal oxidase in sweet potato respiration. Nelson and Rudkin isolated chlorogenic acid and a related compound from sweet potatoes which caused a marked increase in oxygen uptake and carbon dioxide liberation in tissues.

Assisted by Walter, Nelson observed that thoroughly washed potato slices are rapidly killed by ascorbic acid under anaerobic conditions. Cyanide or SH compounds, on the other hand, protect the tissues against this destructive action. They suggested the new proposal, therefore, that "some metal-bearing enzyme might be involved in anaerobic respiration or even glycolysis."

OTHER FIELDS

One is continually impressed by the breadth of interests Nelson has shown. Besides the lines of research work already discussed, he and his associates have made significant contributions in the field of organic reactions. With Ward Evans he examined the electromotive force developed in cells containing the Grignard reagent, while with Arnold Collins he discovered a process by which alkyl groups could be introduced electrolytically into organic structures. Two other of his students, John Northrop and T. C. Taylor, studied the phosphorus and fat linkages in starch. More recently Nelson and Kapp carried out the synthesis of new isomers of octadecenoic acid. Through all this work there runs the same theme, regardless of the subject—the application of sound principles to the solution of interesting problems.

It is difficult in such a short time to indicate the magnitude of the contributions Nelson and his group have made, unless certain comparisons are made. Many investigators are happy to make one or two solid research contributions during their lives. The electronic concept of valence, the quinhydrone electrode, the salt effect on hydrogen ion, kinetic or purification studies of invertase or the crystallization of tyrosinase, the intermediate products of phenol oxidations, any one of which assumes a prominent place in pushing back the frontiers of chemistry, would by ordinary standards be a gratifying product of a lifetime. Summing them together, however, we have a truly prodigious accomplishment for one individual which in part is responsible for Nelson's being classed as one of the great pioneers in chemistry.

TEACHING

Let us now turn our attention to Nelson's magnificent record as a teacher. On this subject words cannot adequately describe our regard for him. His research work may outlive his reputation as a teacher, but those thousands of students who have worked under him or who listened to his beautifully organized "41–42" lectures on organic chemistry regard him as the most inspiring of teachers. We left his lectures wanting to know more about the subject. His approach was simple and direct. It consisted of telling the story so it captured the student's interest. This is not a new technique, but Nelson combined many attributes to make it extraordinarily successful. Among other things he spent long hours preparing his

lectures on elementary organic chemistry, despite the fact that he had taught this same course for more than 30 years. His intimate knowledge of the development of organic chemistry permitted him to inject important side lights into his lectures which kept up student interest.

He was also a wise counselor in his capacity as premedical advisor to the undergraduates. The medical profession should be eternally grateful to him for his insistence that premedical students have sound chemical training at an early date.

In the early thirties Nelson initiated a new approach to the laboratory course in beginning organic chemistry. With the student interest in mind he proposed that the student learn about laboratory methods while working on materials with which he had some familiarity, such as natural products. This helped to bridge the gap between the seemingly remote aspects of the classical laboratory experiments and something with which he was more familiar. Thus, the student prepared caffeine from tea leaves, which necessitated his use of the important processes of extraction, titration, adsorption, fractional crystallization, sublimation, and the melting-point measurement as a criterion of purity. This proved to be a highly successful innovation and only the tremendous increase in student enrollment during and following the last war forced a revision of this plan.

Nelson's course for graduate students, on the history of theories in organic chemistry, was unique and stimulating, and therefore popular. He was so steeped in the minute details of the early developments in chemistry that he could speak in a familiar manner of "old Liebig" or Berzelius.

In his retirement Nelson has not slackened his interest in chemistry. He accepted with enthusiasm the opportunity to rebuild the Chandler Chemical Museum which had been dismantled to make way for the Manhattan Project. He has planned the displays so that the discoverer or inventor of important milestones in chemistry is given appropriate recognition. This venture, like so many others that he has undertaken, is attracting an unusual amount of attention and is proving to have a great educational value.

In 1940 the New York Section of the American Chemical Society awarded Nelson the Nichols Medal for his many contributions to chemistry. Today the American Chemical Society and Columbia University join in recognizing him as a great pioneer in chemistry. Thousands of associates, students, and friends will rejoice as this richly deserved distinction is received by one of their most beloved teachers and scholars.

ALL OVER THE WORLD: 2119 MEMBERS

TREASURER William F. Ehret prepared the following geographical distribution study of the membership in the Division of Chemical Education as of September 1, 1955. It was appended to his official report to the Division's executive committee at their Minneapolis meeting. The full text of the report will appear at a later date.

New York	207	Florida	28	Wyoming	6
Pennsylvania	179	Delaware	26	New Hampshire	5
Ohio	148	Alabama	26	Puerto Rico	5
Illinois	124	Washington, D. C.	24	Montana	2
California	103	West Virginia	21	Alaska	2
Michigan	92	Georgia	20	Nevada	1
Kansas	85	Kentucky	19	Canada	8
Indiana	79	Colorado	19	Cuba	3
Virginia	76	Utah	16	China (Formosa)	2
Massachusetts	71	South Dakota	16	Japan	2
New Jersey	66	Oregon	16	Philippines	1
Texas	66	Nebraska	15	Germany	1
Minnesota	48	Arkansas	15	France	1
Missouri	48	South Carolina	14	Denmark	1
Wisconsin	48	New Mexico	13	Sweden	1
Iowa	43	Maine	12	England	1
Oklahoma	37	Idaho	10	West Africa	1
Tennessee	37	Arizona	10	Pakistan	1
Maryland	34	Rhode Island	8	Netherlands West Indies	1
Connecticut	33	Mississippi	7	Portugal	1
North Carolina	33	North Dakota	7	Greece	1
Washington	30	Hawaii	7	Lebanon	1
Louisiana	29	Vermont	6		

TEXTBOOK ERRORS[1]

IV: The Sensitivity Change of Analytical Balances

KAROL J. MYSELS
University of Southern California,
Los Angeles, California

THE bending of the beam of an analytical balance is generally[2] brought into discussions of sensitivity of analytical balances as an important and occasionally as the main factor. I am indebted to Mr. Milton Gray (now of Thackabery Tool Company) for calling my attention to the lack of significance of this factor and to the fact that it is the relative position of the knife edges that determines the variation of sensitivity with load.

We may measure the sensitivities of a balance by the millimeters deflection d of the pointer per milligram of excess weight on one pan. This may be readily calculated as follows: As shown schematically in the figure, a balance beam weighing B grams, loaded by weights W and $W + w$, reaches equilibrium after deflecting by an angle α under the influence of the moments of three forces with respect to its fulcrum E. These are (*a*) the deflecting force w with a moment $wl \cos \alpha$ where l is the length of the balance arm; (*b*) the restoring force B of the weight of the beam acting at the center of gravity G of the *rigid* part of the oscillating system with a moment $Bg \sin \alpha$, where g is the distance of this center of gravity from the fulcrum; and (*c*) the restoring or deflecting force $2W$ of the two equal parts of the load applied at the midpoint M of the two extreme knife edges, its moment $2W\delta \sin \alpha$, is restoring if M is below the fulcrum (by δ), deflecting if it is above, and zero if M coincides with the fulcrum; *i. e.*, if the three knife edges are exactly in one plane. Thus:

$$wl \cos \alpha = (Bg + 2W\delta) \sin \alpha$$

Introducing the length of the pointer P, we have $\text{tg}\alpha = d/P$ and after rearranging:

$$1/s = (Bg/Pl) + (2\,\delta/Pl)W$$

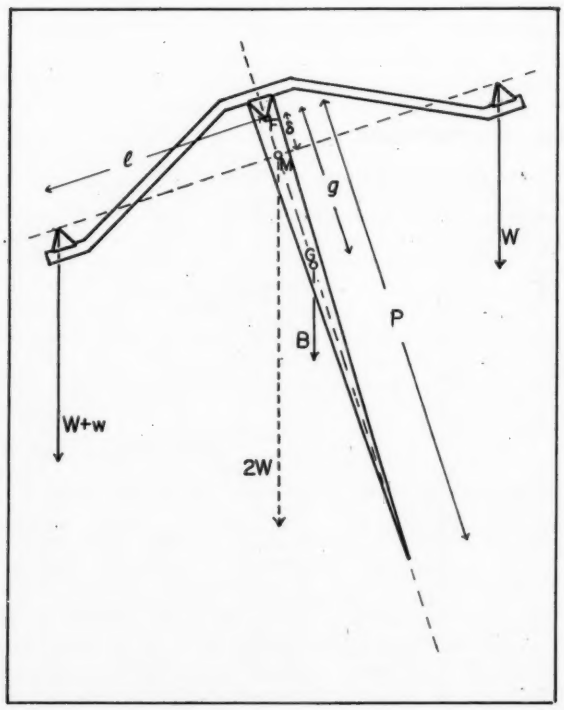
If the beam is rigid the two expressions in brackets are constant for a given balance and the inverse of the sensitivity is a linear function of the load. It increases or decreases depending on the sign of δ. By plotting l/s versus W, a straight line is obtained whose intercept at zero load on the knife edges (*i. e.*, after correcting for the weight of the pans and stirrups) gives g when multiplied by Pl/B and whose slope gives δ when multiplied by $Pl/2$.

On the other hand, if the beam is not rigid both g and δ will increase with W. Hence the above plot of $1/s$ versus W will curve upward. This curvature will be due mainly to δ which would obviously be affected much more than g.

It is thus possible to determine very accurately any bending of the beam as well as the deviation of the knife edges from a plane and the position of the center of gravity, by determining the sensitivity at three widely differing loads.

[1] Suggestions of material suitable for this column are eagerly sought and will be acknowledged. They should be sent with as many details as possible to K. J. M. at the above address.

[2] Since the purpose of this column is to prevent the spread and continuation of errors and not the evaluation of individual texts, the source of the errors discussed will not be cited. The error must occur in at least two independent standard books to be presented.



Mr. G. S. Clayson, President of Wm. Ainsworth and Sons, kindly told me that he once had a standard beam adjusted so carefully that it showed the same sensitivity of five divisions per two mg. at no load and at the full load of 200 g. When this beam was overloaded by 400 per cent to one kg., the sensitivity increased to $5^1/_8$ divisions per two mg. Assuming reasonable constants these results are compatible within experimental error with a perfectly rigid beam whose knife edges are one micron (four millionths of an inch) out of plane, or alternately that the maximum possible bending of the beam was one micron under a load of one kg., *i. e.*, 0.2 microns at full normal load.

I have recently tested balances of two other makes and could not detect any bending up to 250 per cent of full load. To place any bending amounting to a small fraction of a micron in proper perspective it should be compared with the other dimensions. In a balance which has a zero load sensitivity of 2.5, g amounts to about 150 microns. If this sensitivity decreases by 20 per cent at 200 g. load, δ is about 4 microns. Hence the bending of the beam, while it must, of course, occur, can only be a very secondary factor.

It may be worth noting, incidentally, that if the sensitivity of a balance is independent of load, its period will be increasing rapidly with load, because constant sensitivity means that the restoring torque remains the same while the moment of inertia rises manyfold.

CROSSWORD PUZZLE

BERT H. CLAMPITT
Oak Ridge, Tennessee

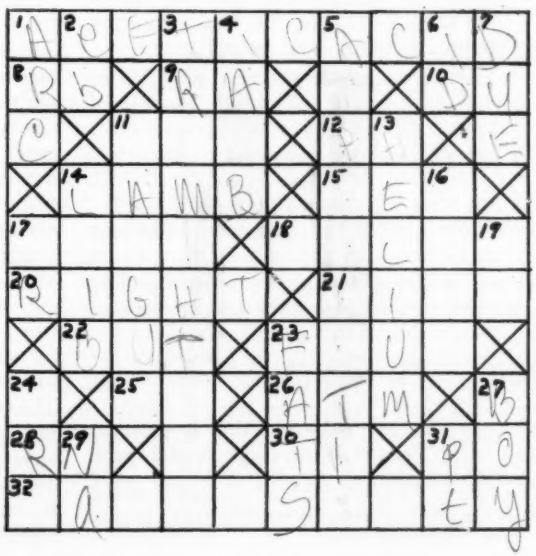
Across

1. Vinegar (two words)
8. Rubidium
9. Radium
10. Dysprosium
11. Jewel
12. Acidity
14. Young sheep
15. To cut down
17. Keep in order
18. Drawing room
20. Correct
21. Jail ——
22. Conjunction
23. A quarrel
25. Aviation ordnanceman (abbreviation)
26. Atmosphere (abbreviation)
28. Radon
30. Titanium
31. Polonium
32. The 125th national A. C. S. meeting was held here (two words)

Down

1. Part of a circle
2. Columbium
3. Large
4. Poetic foot
5. Chemicals are arranged in —— order
6. Fundamental mass of life
7. To color
11. Lead ore
13. Rare gas
14. Capital of Peru
16. That which is said
17. Note on the scale
19. Neodymium
23. Lards
24. Kind of ship
27. Male child
29. Sodium
31. Platinum

(See page 544 for solution.)



THERMODYNAMIC CALCULATIONS[1]

I: Free-energy Functions and Heat-content Functions

JOHN L. MARGRAVE
University of Wisconsin, Madison, Wisconsin

Most textbooks of physical chemistry and thermodynamics emphasize the calculation of equilibrium constants, ΔF and ΔH values at other than standard temperatures by the use of ΔC_p and heat capacity equations. Also, the log K or log P versus $1/T$ plot and the evaluation of heats of reaction from its slope are usually discussed at length. The usefulness of the free-energy function and heat-content function (which are tabulated quantities) in such calculations is seldom more than mentioned, especially in connection with the computation of a heat of reaction from a series of equilibrium points. The student is left with the idea that this latter approach to thermodynamic calculations must be undesirable, difficult, or impractical. Actually, extensive tabulations of free-energy and heat-content functions are readily available, and these functions are easy to use. One can often obtain more reliable information about the heat of a reaction from a given set of experimental data through a free-energy function treatment than by any other means.

DEFINITIONS AND METHODS FOR CALCULATION

The free-energy function at a temperature T may be expressed in terms of the ordinary thermodynamic quantities. One may rearrange the basic equation relating free energy, enthalpy, and entropy:

$$F_T = H_T - TS_T \tag{1}$$

as

$$\left(\frac{F_T - H_T}{T}\right) = -S_T \tag{2}$$

Then, by adding the quantity $\left(\frac{H_T - H_{T\text{ref.}}}{T}\right)$ (the heat content above a reference temperature, usually 0°K. or 298°K., divided by T), one gets the free-energy function:

$$\left(\frac{F_T - H_{T\text{ref.}}}{T}\right) = -S_T + \left(\frac{H_T - H_{T\text{ref.}}}{T}\right) \tag{3}$$

From this equation, it is apparent that free-energy functions can be evaluated from experimental heat-capacity measurements since:

$$S_T = \int_0^{T_1} Cp\, d \ln T + \frac{\Delta H_{tr}}{T_1} + \int_{T_1}^{T_2} Cp\, d \ln T + \ldots + \int_{T_i}^{T} Cp\, d \ln T \tag{4}$$

and

$$\left(\frac{H_T - H_{T\text{ref.}}}{T}\right) = \frac{1}{T}\left[\int_{T_{\text{ref.}}}^{T_1} Cp\, dT + \Delta H_{tr} + \int_{T_1}^{T_2} Cp\, dT + \ldots + \int_{T_i}^{T} Cp\, dT\right] \tag{5}$$

The choice of a reference temperature is one point on which universal agreement has not been reached. For theoretical reasons arising in calculation of free-energy functions of gases, the function $[(F - H_0)/T]$ is often tabulated where $T_{\text{ref.}} = 0$°K. From an experimental viewpoint, the function $[(F - H_{298})/T]$ is often preferred since most calorimetric measurements are made at or near 298°K. Interconversion of free-energy functions with 0°K. as the reference temperature to free-energy functions with 298°K. as the reference temperature is accomplished by use of the function $[(H_{298} - H_0)/T]$.

Solids and liquids must be treated by the method outlined above since there is no satisfactory theory for computing their heat capacities and energies. Gases may be treated either by the method involving experimental data, or free-energy functions and other thermodynamic properties may be calculated for ideal gases by statistical mechanics when sufficient data are available for the molecule from spectroscopic, or electron-diffraction studies. It is necessary to have sufficient information to allow calculation of the partition function which expresses the distribution of gaseous atoms or molecules over possible electronic, vibrational, and rotational energy states as a function of temperature. Methods for computing free-energy functions for gases were developed by Giauque (*1*) and are reviewed and illustrated by Wilson (*2*) and Wenner (*3*). The free-energy function may be computed in essentially independent parts contributed by the translational, electronic, vibrational, and rotational degrees of freedom. Equations follow for computing free-energy functions for monatomic, diatomic, or linear polyatomic molecules.

[1] Presented at the 126th Meeting of the American Chemical Society, New York, September, 1954.

CALCULATING FREE-ENERGY FUNCTIONS (4)

Monatomic Gases. For monatomic gases use only the translational and electronic parts of the equations given below for diatomic and linear polyatomic molecules. There are no vibrational or rotational contributions for atoms.

Diatomic or Linear Polyatomic Molecules. For linear polyatomic molecules (two or more atoms), the various contributions to the free-energy function are:

Translation:	$-6.8635 \log M - 11.4392 \log T + 7.2820$
Rotation:	$4.5757 (-\log I - \log T + \log \sigma) + 6.3359$, or $4.5757 [-\log (I' \times 10^{39}) - \log T + \log \sigma] + 2.7676$
Vibration:	$1.9872 \sum_i \ln (1 - e^{-x_i})$, or $4.5757 \sum_i \log (1 - e^{-x_i})$
Electronic:	$-4.5757 \log Q_{el}$

where M = molecular weight in atomic-mass units; T = temperature in degrees Kelvin; I = moment of inertia of molecule in mass units-Angstroms^2; I' = moment of inertia of molecule in gram-cm.^{2}; σ = the symmetry number, the number of indistinguishable ways in which a molecule may be oriented by rigid rotation; $x_i = h\nu_i/kT = hc\omega_i/kT$ where ν_i is the fundamental vibrational frequency and ω_i the vibrational energy; and Q_{el}, the electronic partition function, $= g_0 + g_1 e^{-(\epsilon_1 - \epsilon_0)/kT} + g_2 e^{-(\epsilon_2 - \epsilon_0)/kT} + g_3 e^{-(\epsilon_3 - \epsilon_0)/kT} + \ldots$ where g_i is the statistical weight of the ith state which has energy ϵ_1 above the ground state which has weight g_0 and energy ϵ_0.

The four contributions to the free-energy function may be combined into a single equation:

$$\left(\frac{F - H_0}{T}\right)^\circ = -6.8635 \log M - 16.0149 \log T - 4.5757 [\log I - \log \sigma + \log Q_{el} - \sum_i \log (1 - e^{-x_i})] + 13.6179 \text{ cal. deg.}^{-1} \text{ mole}^{-1}$$

Among the aids for calculation of free-energy functions are (*a*) the tables of molecular constants and molecular and atomic energy levels of Herzberg (*5*) and Moore (*6*); (*b*) the table of translational contributions to the free-energy function and entropy without molecular weight by Gilles and Gallup (*7*); (*c*) the table of vibrational contributions to the heat capacity, entropy, heat-content function, and free-energy function of Johnston, Savedoff, and Belzer (*8*); (*d*) unpublished nomographs of Margrave, Gilles, and Gallup; and (*e*) electronic computers which have been successfully applied to computation of thermodynamic functions by Savedoff, Belzer, and Johnston (*9*), Gilles and Kolsky (*10*), Friedman and Haar (*11*), and Katz and Margrave (*12*).

LITERATURE SOURCES

As will be shown later in this paper, the compilation of extensive tables of free-energy and heat-content functions is highly desirable, and once completed would probably promote the discarding of the ΔC_p approach to calculations at other than standard temperatures. Unfortunately, there is no one complete summary of free-energy functions and other thermodynamic functions calculable from heat-capacity and spectroscopic data, and this lack of an organized source frequently discourages the use of free-energy functions. There are, however, several important sources of data which are usually available and which may be useful in many cases.

Thermodynamic properties of many organic compounds are summarized in National Bureau of Standards Circular C461 (*13*) which lists physical and thermodynamic data incouding free-energy and heat-content functions for O, H, N, C, O_2, H_2, OH, H_2O, N_2, NO, C, CO, CO_2, paraffins, alkyl benzenes, alkylcyclohexanes, monoolefins, and acetylenes up to 1500° K. In addition, these data plus additional data for cyclopentanes, diolefins, cyclopentenes, cyclohexenes, styrenes, naphthalenes, and many organic sulfur compounds are included in the recent American Petroleum Institute Research Project 44 report (*14*).

The most extensive tabulation of thermodynamic data for inorganic compounds is the National Bureau of Standards Circular 500 (*15*) which lists values of ΔH_f at 0° and 298°K., and ΔF_f, log K_f, S^0, and C_p at 298°K. A partially completed series of tables is Selected Values of Chemical Thermodynamic Properties, Series III, which is being issued in sections and thus far includes free-energy and heat-content function data over the range 0–5000°K. for many elements, a few inorganic compounds, and the hydrocarbons up to C_8.

The tables of Brewer, Bromley, Gilles, and Lofgren (*16*) cover all the thermodynamic properties over the range 0–2000°K. for the solid and gaseous elements, common gases, and inorganic halides. Latimer has listed free-energy functions for some gaseous elements and diatomic gases between 2000° and 5000°K. (*17*). Kelley has evaluated free-energy functions for several elementary solids and gases (*18*).

Tables of free-energy functions and other thermodynamic data for many gaseous molecules are also given by Ribaud (*19*), in the NBS-NACA Tables of Thermal Properties of Gases (*20*), and in various National Bureau of Standards Reports on Thermal Properties of Fluorine Compounds.

Except for these sources, one must search the literature for free-energy function data. In particular, likely sources are papers reporting heat-capacity measurements, vapor-pressure measurements, or new spectroscopic data which often contain calculated free-energy functions or sufficient data to allow their computation. For example, see the low-temperature heat-capacity measurements of Giauque; the vapor-pressure studies of Johnston and co-workers; and calculations of thermodynamic functions from spectroscopic data by Cleveland, Meister, and others. Subsequent papers in this series will include summaries of recent data for con-

densed and gaseous elements, oxides, sulfides, and hydroxides.

EXAMPLES OF THE USE OF FREE-ENERGY FUNCTIONS

Changes in the free-energy function during a chemical reaction may be defined and computed in an analogous way to changes in enthalpy, entropy, or free energy. Thus, for free-energy functions with 0°K. as $T_{ref.}$:

$$\Delta\left(\frac{F-H_0}{T}\right)_{reaction} = \Sigma\left(\frac{F-H_0}{T}\right)_{products} - \Sigma\left(\frac{F-H_0}{T}\right)_{reactants} \quad (6)$$

$$= \left(\frac{\Delta F}{T}\right)_{reaction} - \left(\frac{\Delta H_0}{T}\right)_{reaction} \quad (7)$$

If $[(F - H_{298})/T]$ functions are used:

$$\Delta\left(\frac{F-H_{298}}{T}\right) = \left(\frac{\Delta F}{T}\right)_{reaction} - \left(\frac{\Delta H_{298}}{T}\right)_{reaction} \quad (8)$$

Since one may evaluate the free-energy functions from heat-capacity or spectroscopic data, it is possible to obtain values for either ΔF or $\Delta H_{T_{ref.}}$ when the other quantity is known. From a series of independent $\Delta F_{reaction}$ measurements, one can evaluate a number of equally weighted $\Delta H_{reaction}$ values. Conversely, when $\Delta H_{T_{ref.}}$ has been evaluated, one can use the change of free-energy function for the reaction and calculate $\Delta F_{reaction}$.

The dimensions of the free-energy function are the same as those of entropy (cal. deg.$^{-1}$ mole^{-1}) and, of course, $[(F - H_{298})/T]$ is equal to $-S_{298}$ at 298°K. Entropies are relatively easy to estimate (*21*), and so are free-energy functions. The free-energy function is primarily determined by the molecular weight and temperature, and one may estimate values for new or unknown compounds by comparison with other substances of similar formulas and molecular weights. Free-energy functions are usually slowly varying functions of temperature and may be obtained with fair accuracy from values given at wide intervals by simple interpolation and extrapolation procedures. The change of free-energy function for a given type of reaction is nearly always close to some characteristic value, and also is a slowly varying function of temperature. Changes of free-energy functions for chemical reactions can often be estimated with only a small uncertainty even when the individual free-energy functions for the products and reactants are not known. The quantity $[(F - H_{298})/T]$ has a maximum value at 298°K.

As examples to illustrate the use of free-energy functions in thermodynamic calculations, it will be worth while to consider the calculations for (*a*) the sublimation of a solid element to form gaseous atoms; (*b*) the decomposition of a solid to form another solid and a gas; and (*c*) the equilibrium among several gaseous species.

(1) Consider the sublimation of chromium metal. Several measurements of the equilibrium vapor pressure at temperatures from 1283° to 1561°K. have been reported (*22*). From each pressure measurement one may calculate a value of $\Delta F/T$ and, with the aid of the change of free-energy function, a value for ΔH_0, the heat of sublimation at 0°K. as shown in Table 1. The free-energy functions for the gaseous and solid chromium are given in columns 2 and 3, and $-\Delta[(F - H_0)/T]_{sub.}$ is given in column 4. The ΔH_0 values in the last column show a standard deviation from the mean of less than 0.2 kg.-cal./mole. Treatment of data of this type by determining the slope of the log K versus $1/T$ plot rarely gives accuracy of better than two or three per cent.

The alternative use of the $[(F - H_{298})/T]$ functions would give ΔH_{298} of sublimation which differs from ΔH_0 of sublimation by the amount:

$$(H_{298} - H_0)_{Cr(g)} - (H_{298} - H_0)_{Cr(s)} = 1481 - 1000 \text{ cal.} = 0.48 \text{ kg.-cal./mole}$$

(2) Consider the decomposition of NaO_2(s).

$$2NaO_2(s) = Na_2O_2(s) + O_2(g)$$

The free-energy functions for the two solids may be evaluated from low-temperature heat capacities for temperatures below 298°K.; no high-temperature data are available (*23*). Thermodynamic data for O_2(g) are well known. As shown in Table 2, one computes $\Delta[(F - H_{298})/T]_{298} = -16.2$ e.u., and with $\Delta H_{298} =$ 400 cal. (*24*), one finds $\Delta F/T = -2.8$ e.u., and $P_{O_2} =$ 4 atm. at 298°K. At 600°K., with an estimated free-energy function change of 14 e.u., one calculates $P_{O_2} = (40 \pm 20)$ atm. Recent measurements indicate that the equilibrium oxygen pressure is actually around 30 atm. at 600°K. (*25*).

(3) Consider the equilibrium:

$$F_2(g) = 2F(g)$$

TABLE 1
Cr (solid) = Cr (gas)

T°K.	$-\left(\frac{F-H_0}{T}\right)_{Cr(g)}$ e.u.	$-\left(\frac{F-H_0}{T}\right)_{Cr(s)}$ e.u.	$-\Delta\left(\frac{F-H_0}{T}\right)_{sub.}$ e.u.	$-\Delta F/T = -R \ln P$ e.u.	$\frac{\Delta H_0}{T}$ e.u.	ΔH_0 kg.-cal. mole^{-1}
1283	43.92	9.91	34.01	38.89	72.90	93.54
1377	44.27	10.30	33.97	33.81	67.78	93.33
1418	44.43	10.47	33.96	32.18	66.14	93.79
1455	44.55	10.62	33.93	30.35	64.28	93.53
1497	44.69	10.78	33.91	28.50	62.41	93.43
1561	44.90	11.04	33.86	25.74	59.60	93.03

TABLE 2
$2NaO_2(solid) = Na_2O_2(solid) + O_2(gas)$

T°K	$-\left(\frac{F-H_{298}}{T}\right)_{2NaO_2}$ e.u.	$-\left(\frac{F-H_{298}}{T}\right)_{Na_2O_2}$ e.u.	$-\left(\frac{F-H_{298}}{T}\right)_{O_2}$ e.u.	$-\Delta\left(\frac{F-H_{298}}{T}\right)$ e.u.	$\frac{\Delta H_{298}}{T}$ e.u.	$-\frac{\Delta F}{T}$ e.u.	P_{O_2} atm.
298	55.4	22.6	49.0	16.2	13.4	2.8	4
600	(64)	(28)	50.4	(14 ± 1)	6.7	(7.3 ± 1)	40 ± 20

One can obtain the values of the free-energy functions from the literature (*26*) and evaluate the change of free-energy function as shown in Table 3. ΔH_0, which is equal to the dissociation energy, $D(F_2)$, can be calculated if $\Delta F/T$ is known. In column 5 of Table 3 are a few experimental values of $-\Delta F/T$ obtained by pressure-temperature measurements on a closed system containing fluorine (*27*). The values of ΔH_0 show no systematic variation, and give an average of $\Delta H_0 = 36.66 \pm 0.15$ kg.-cal./mole. Other experiments of this type have given values from 32 to 38 kg.-cal./mole for $D(F_2)$.

EXAMPLES OF THE USE OF HEAT-CONTENT FUNCTIONS

The heat-content function $[(H_T - H_{T_{ref.}})/T]$, where $T_{ref.}$ is usually 0° or 298°K., is useful for computing heats of reaction at temperatures other than that at which the reaction was studied. For example, (*a*) spectroscopically determined dissociation energies are for 0°K., yet they are often needed for 298°K. where calorimetric measurements are commonly carried out; (*b*) interconversion from $[(F - H_0/T]$ to $[(F - H_{298})/T]$ requires the function $[(H_{298} - H_0)/T]$; and (*c*) heats of vaporization or sublimation determined at one temperature may be needed at some other temperature.

One may conveniently apply this thermochemical cycle:

$$\begin{array}{ccc} \text{Reactants at } T_2 & \xrightarrow{\Delta H_{T_2}} & \text{Products at } T_2 \\ \uparrow (H_{T_2} - H_{T_1})_{reactants} & & \uparrow (H_{T_2} - H_{T_1})_{products} \\ \text{Reactants at } T_1 & \xrightarrow{\Delta H_{T_1}} & \text{Products at } T_1 \end{array}$$

Thus:

$$\Delta H_{T_2} = \Delta H_{T_1} + [(H_{T_2} - H_{T_1})_{products} - (H_{T_2} - H_{T_1})_{reactants} \quad (9)$$

A typical application is in the case of B_2O_3 vaporization (*28*). From a free-energy function treatment of the vapor-pressure data, $\Delta H_0 = 89.4$ kg.-cal./mole. To evaluate $\Delta H_{1500°K.}$, one uses the data $(H_{1500} - H_0)_{B_2O_3(g)} = 28.66$ kg.-cal/mole and $(H_{1500} - H_0)_{B_2O_3(l)} = 40.48$ kg.-cal./mole. This gives $\Delta H_{1500°K.} = 77.6$ kg.-cal./mole in good agreement with the slope of the log P versus $1/T$ plot of Speiser, Naiditch, and Johnston (*29*).

LITERATURE CITED

(1) Giauque, W. F., *J. Am. Chem. Soc.*, **52**, 4808–15 (1930).
(2) Wilson, E. B., Jr., *Chem. Revs.*, **27**, 17–38 (1941).
(3) Wenner, R. R., "Thermodynamical Calculations," McGraw-Hill Book Co., Inc., New York, **1941**, pp. 114–35.
(4) Rossini, F. D., "Chemical Thermodynamics," John Wiley & Sons, Inc., New York, **1950**, pp. 187–8.
(5) Herzberg, G., "Molecular Spectra and Molecular Structure I. Spectra of Diatomic Molecules," 2nd ed., D. Van Nostrand Co., Inc., New York, **1950**, "Molecular Spectra and Molecular Structure II. Infrared and Raman Spectra," D. Van Nostrand Co., Inc. New York, **1945**.
(6) Moore, C., "Atomic Energy Levels," National Bureau of Standards Circular 467, Vols. I and II, **1949** and **1952**.
(7) Gilles, P. W., and G. A. Gallup, *Trans. Kansas Acad. Sci.*, **56**, 465–8 (1953).
(8) Johnston, H. L., L. Savedoff, and J. Belzer, ONR Report NAVEXOS, **1949**, p. 646.
(9) Savedoff, L., J. Belzer, and H. L. Johnston, *Proc. Sci. Computation Forum*, IBM, Inc., New York, **1948**, pp. 74–6; "Proceedings of the Third Symposium on Combustion, Flame, and Explosion Phenomena," Madison, Wisconsin, **1948**, pp. 595–9.
(10) Kolsky, H. G., and P. W. Gilles, *J. Chem. Phys.*, **22**, 232–3 (1954).
(11) Friedman, A. S., and L. Haar, National Bureau of Standards Report 3101, Feb. 28, **1954**.
(12) Katz, J. T., and J. L. Margrave, Unpublished work, University of Wisconsin, in which the IBM card-programed electronic calculator was used, 1954.
(13) "Selected Values of Properties of Hydrocarbons," National Bureau of Standards Circular C461, **1947**.
(14) "Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds," American Petroleum Institute Project 44 Report, Carnegie Press, Pittsburgh, **1953**.
(15) "Selected Values of Chemical Thermodynamic Properties," National Bureau of Standards Circular 500, **1952**.

TABLE 3
$F_2 = 2F$

T°K.	$-\left(\frac{F-H_0}{T}\right)_{F_2}$ e.u.	$-\left(\frac{F-H_0}{T}\right)_{2F}$ e.u.	$-\Delta\left(\frac{F-H_0}{T}\right)$ e.u.	$-\left(\frac{\Delta F}{T}\right)_{exptl.}$ e.u.	$\frac{\Delta H_0}{T}$ e.u.	ΔH_0 kg.-cal. mole^{-1}
760	48.33	75.25	26.92	21.51	48.43	36.81
850	49.20	76.41	27.21	15.51	42.72	36.31
954	50.14	77.64	27.50	11.03	38.53	36.76
1000	50.50	78.14	27.64	8.94	36.58	36.58
1061	50.98	78.75	27.77	7.05	34.82	36.94
1112	51.36	79.25	27.89	5.03	32.92	36.61

(16) Brewer, L., L. Bromley, P. W. Gilles, and N. Lofgren, Papers 3, 5, 6, and 7 in Quill, L. L. "Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics," NNES IV-19B, McGraw-Hill Book Co., Inc., New York, 1950.
(17) Latimer, W. M., Revision of MDDC 1462, 1952.
(18) Kelley, K. K., U. S. Bureau of Mines Bulletin 383, 1935.
(19) Ribaud, M., "Constantes Thermodynamiques des Gaz aux Temperatures Elevés," Publication No. 266 of the French Air Ministry, Paris, 1952.
(20) "The NBS-NACA Tables of Thermal Properties of Gases," National Bureau of Standards, Washington, D. C., 1949–51.
(21) Latimer, W. M., *J. Am. Chem. Soc.*, **73**, 1480–2 (1951).
(22) Speiser, R., H. L. Johnston, and P. E. Blackburn, *ibid.*, **72**, 4142–3 (1950).
(23) Todd, S. S., *ibid.*, **75**, 1229–31 (1953).
(24) Margrave, J. L., and P. W. Gilles, Unpublished work, University of Kansas, Lawrence, Kansas, 1950.
(25) Friedman, P. J., and J. L. Margrave, Unpublished work, University of Wisconsin, 1954.
(26) Cole, L. G., M. Farber, and G. W. Elverum, Jr., *J. Chem. Phys.*, **20**, 586–90 (1952).
(27) Doescher, R. N., *ibid.*, **20**, 330–4 (1952).
(28) Soulen, J. R., P. Sthapitanonda, and J. L. Margrave, *J. Phys. Chem.*, **59**, 132–6 (1955).
(29) Speiser, R., S. Naiditch, and H. L. Johnston, *J. Am. Chem. Soc.*, **72**, 2578–80 (1950).

A THREE-DIMENSIONAL PERIODIC CHART

OCTAVIA S. SELL
Anderson College, Anderson, South Carolina

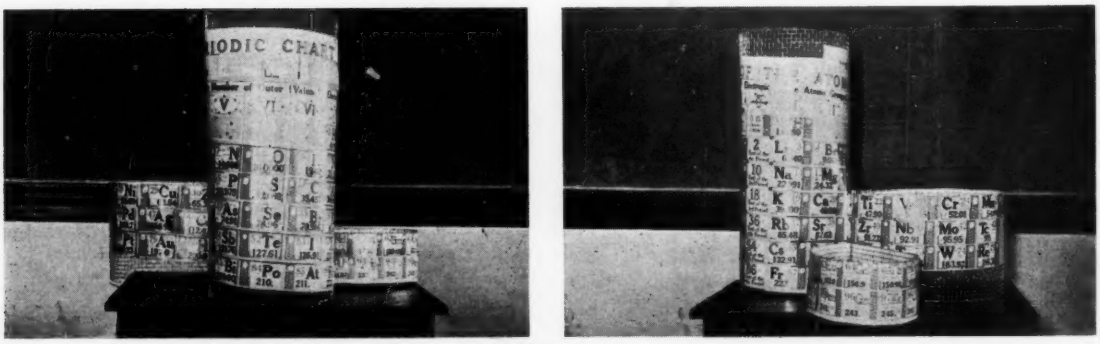


Figure 1

Several three-dimensional arrangements of the periodic law have been suggested, but they either lack the valuable data of the Hubbard chart or do not fully show the relationship between the atoms which are receiving electrons into outer orbits and those receiving electrons into inner orbits.

To prepare a chart for classroom use which would make all these features more easily seen and understood, we made a three-dimensional model from the conventional Hubbard chart, as shown in Figure 1. The framework was made of "hardware cloth" cut to the dimensions given in Figure 2. Strips cut from the chart were attached to the framework after shaping.

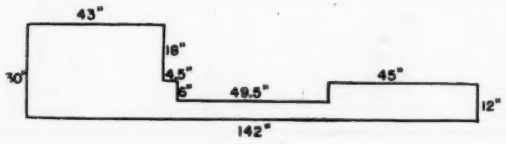


Figure 2

The tallest section is composed of two loops, one containing the alkali metals and the inert gases, the other containing Groups II-A, III-B, IV-B, V-B, VI-B, and VII-B.

A third loop contains the transition metals, Groups III-A, IV-A, V-A, VI-A, VII-A, VIII (the triads), I-B, and II-B. The fourth loop contains the rare earths, both the lanthanide and the actinide series.

EMPHASIS ON EMPATHY[1]

Why is Technical Report Writing an Agony?

W. H. WALDO
Monsanto Chemical Company, St. Louis, Missouri

No matter what part you play in your report system you probably think of reports as no better than a necessary evil. Frequently, they represent nothing but an agonizing ordeal. Such is the general attitude of authors, editors, typists, librarians, and report readers.

Much has been written and said about how poor technical reporting is, how scientists hate to write reports, how to write good reports, and how and when reports ought to be written. But how many have faced the fundamental issue? Why is report writing or reading so distasteful when writing and reading magazines, newspapers, who-done-its, and books on mental health have such avid supporters?

Ask anyone who writes or reads reports and you get a naive but honest answer. "I'm just not a good writer," the scientist complains.

"Reports are written so poorly," the reader agrees.

In trying to solve these problems, in trying to reduce these subjective complaints to objective faults of poor grammar, timing, format, style, or jargon, we have overlooked the personality of the other guy—the reader or writer, whichever we are not at the moment.

If we look closely at the problems and have a knowledge of a cross section of the people who contribute to the stormy atmosphere surrounding reports, we are led to a conclusion that can be expressed in two words—no empathy—no projection of yourself into the other fellow's position.

The absence of empathy for your readers has given rise to laziness and fear on the part of inept authors. The absence of empathy for your authors has given rise to stubborn prejudice and juvenile convictions on the part of reactionary readers. No major improvement in technical reporting will be achieved until these attitudes are either changed or widely understood and compensated for.

Technical authors show their laziness in many ways. There are few organizations that get reports written without a considerable amount of cajoling, and often threats. When the report shows up for typing, it is abominably scribbled, full of fantastically conceived abbreviations, misspelled words, poor grammar and punctuation, and is crudely thrown together. If the author is asked to proofread his own report after typing or composing, it is done only out of courtesy. Few authors have the interest to examine a document critically for errors. Proofreading is hard mental effort and requires an attention discipline seldom evident in technical authors.

No greater indictment of the laziness of authors has been levied than the recent enthusiastic reception ghost writing received. Ghost writing of reports is taking away from scientists the responsibility of accounting for their laboratory creations.

Although laziness may have the technical author chained, fear has him paralyzed. The absence of positive statements in reports has become a universal criticism. Why? Listen to Aristotle for the time-honored reason: "It is because there is less opportunity of error in generalities that soothsayers express themselves in general terms of their subject."

Science is known as "exact!" Listen to this modern-day example of our ancient soothsayer habit, taken from an actual report: "The wavelengths *tentatively* assigned are *thought to have* a *probable* error of *less than* 0.02 Angstrom units."

That tenuous statement is an example of the fear of criticism found in technical communications in our "exact" science of physics!

Those who seem to know exclaim that more basic, fundamental research is sorely needed in this country. One answer may be that there are few scientists in the country fearless enough to publish any discovery really new because they remember with fear in their hearts the beating phlogiston took and the laugh universal ether received. They are so afraid of being wrong that they essay nothing. They have no faith in their own scientific observations.

If those who call themselves "scientists" would eschew laziness and fear, they would soon find their ineptness in writing disappearing.

But let us not hold the authors solely responsible for poor shape in which we find technical communications. Before a telephone communication system is complete, the listener must lift the phone and then must listen.

Report readers in industrial management have only begun to provide realistic reporting systems. Many systems are as archaic and inefficient as the rural party-line telephone system. Such systems distribute reports to all types of reader. But the busy executive

[1] Presented before the Division of Chemical Literature at the 127th Meeting of the American Chemical Society, Cincinnati, March, 1955.

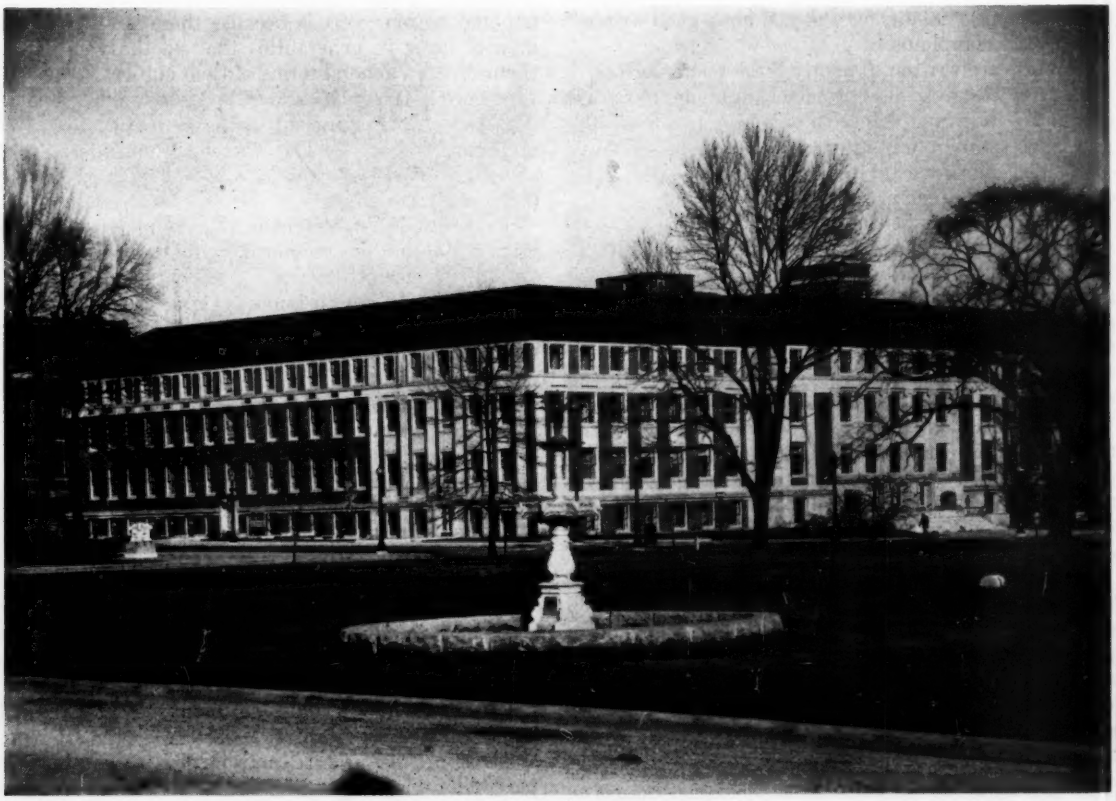
says the reports are too long and the co-worker scientist says that they do not give sufficient details. There is too much "jargon" for the general reader; the specialized reader insists on its presence. The pull-and-haul instructions given authors are enough to throw fear into a Sinclair Lewis.

Well-meaning executives often fail to practice what they preach in their attempts to instruct report writers. How frequently have you heard these words? "Avoid vague statements—be clear and concise." The truth of the matter usually is that the author thinks his writing is as highly specific and free from foggy notions and verbosity as he can make it.[1] Criticism should be as crystal clear as the critic can make it; and as specific.

Neither author nor reader has sufficient empathy for the other to reach the degree of communication necessary for modern industrial team research. They should learn both to understand and to appreciate the other man's point of view.

In this age of specialization we must all realize and appreciate the vertical type of knowledge most of us have. Most of us know a great deal about a few things and very little about most things. All A's in school, Nobel-prize winner, or vice-president does not mean "all-knowing." The agony of writing will all but disappear if you understand and appreciate your reader. Meet him. Study him. Write for him.

A little more consideration for the other fellow will do more to improve the status of technical communications than ten lessons in grammar or screams for clarity and conciseness.



New Chemistry Building, Purdue University

NOMENCLATURE FOR CONDUCTANCE[1]

RAYMOND M. FUOSS
Yale University, New Haven, Connecticut

In attempting to prepare a compact presentation of some recent work on conductance, the author noticed that the repetition of a number of wordy expressions became monotonous. Consider, for example, how often the phrase, ". . . figure in which the equivalent conductance is plotted against the square root of concentration" occurs in a paper on conductance. It is therefore proposed to refer to this curve as a *phoreogram* (from φορέω—carry, and γράφω—write; with obvious ellipsis). In general, two types of phoreogram are found experimentally: those which approach the Onsager tangent from above as concentration approaches zero, and those which approach it from below. These may be succinctly described as *anabatic* (ἀναβαίνω—go up) and *catabatic* (καταβαίνω—go down) phoreograms, respectively, while the occasional curve which lies on the tangent for a moderate range of concentration would consistently be called *parabatic* (παραβαίνω—go by the side of).

In discussions of electrolytes, it is frequently necessary to speak of a "solvent of low dielectric constant," when what is implied is that in such a solvent the coulomb potential of a pair of oppositely charged ions is large compared to their average thermal energy, and that the ions therefore cluster together into pairs, triples, or still higher aggregates. The term *smenogenic* (σμῆνος—swarm) is suggested for such solvents; conversely, a solvent in which the dielectric constant is high enough to prevent ion association would be called *smenocolytic* (κωλύω—hinder).

Finally, the historical categories of "strong" and "weak" electrolytes often lead to circumlocutions or ambiguities. For example, sodium chloride is called a strong electrolyte and iodic acid a weak electrolyte; nevertheless, their phoreograms in liquid ammonia are strikingly similar, despite the marked difference shown in water. Furthermore, the phoreogram of sodium chloride in ammonia resembles the curve for iodic acid in water much more than it does the curve of a typical strong electrolyte in water. Conventional nomenclature thus forces us into the awkward position of asserting that sodium chloride is a strong electrolyte in water and a weak one in ammonia; the difficulty, of course, lies in the confusion of two distinct phenomena which were not clearly distinguished in Ostwald's day. It is therefore suggested that sodium chloride be called an *ionophore*, defined as a substance in which ions and only ions are present in the crystal lattice. The contrasting category would then be the *ionogens*, those substances with molecular crystal lattices which can produce electrolytes by reaction when dissolved in appropriate solvents. We might then properly refer to iodic acid as a weak ionogen in aqueous solution and as a strong ionogen in ammonia; *weak* and *strong* thus refer to the acid-base equilibria between solute and solvent. The traditional meanings of these two words can therefore be preserved if they are reserved for the above usage and are not forced to do double duty. The familiar term "associated," with suitable qualifiying adverbs, can then be used to describe the relative magnitude of the conductance in various solvents.

The usefulness of the proposed terminology is shown by the following equivalent statements:

(1) The conductance curve of sodium chloride in water approaches the Onsager tangent from above, because sodium chloride is a strong electrolyte in water; that is, the potential energy of a (hydrated) sodium ion and a (hydrated) chloride ion in water is at best of the order of kT, and therefore ion pairs are unstable. For iodic acid in water, the conductance curve is concave down, as a consequence of the presence of molecular HIO_3 in solution. The latter species is in equilibrium with a molecular addition compound $H_2O{\cdot}HIO_3$, which rearranges to the ion pair $H_3O^+{\cdot}IO_3'$, which then dissociates into free ions. Disregarding the water (which is in excess at substantially constant concentration), we may then write $[H^+]\ [IO_3']/[HIO_3] = K$. We therefore say that iodic acid in water is a weak electrolyte, compared to sodium chloride in the same solvent. In liquid ammonia, however, both solutes give conductance curves which approach the limiting tangent from below. This downward deviation from the limiting law at nonzero concentrations is caused by the formation of ion pairs; in ammonia, with a dielectric constant only one-quarter that of water, ion pairs are stabilized by their high electrostatic potential energy. Iodic acid is as strong an electrolyte in ammonia as sodium chloride, because ammonia is a much stronger base than water and the solute is therefore completely ionized, although only partially dissociated into free ions.

(2) The phoreogram of sodium chloride in water is anabatic, because the solute is an ionophore which naturally is unassociated in this smenocolytic solvent. Iodic acid is only a fairly strong ionogen in water and hence exhibits a catabatic phoreogram. In ammonia, both solutes give catabatic phoreograms, the former because the ionophore is moderately associated in the smenogenic solvent ammonia, the latter because it is a very strong ionogen in ammonia and the resulting ions are likewise moderately associated.

ACKNOWLEDGMENT

Acknowledgment is made to N. N. T. Samaras of Monsanto and to Ralph L. Ward of Yale for their help.

[1] Contribution No. 1305 of the Sterling Chemistry Laboratory, Yale University, New Haven, Connecticut.

A MAGNETICALLY-ACTUATED GLASS PUMP FOR CIRCULATING GASES

R. J. BRUNFELDT and V. C. F. HOLM
Phillips Petroleum Company, Bartlesville, Oklahoma

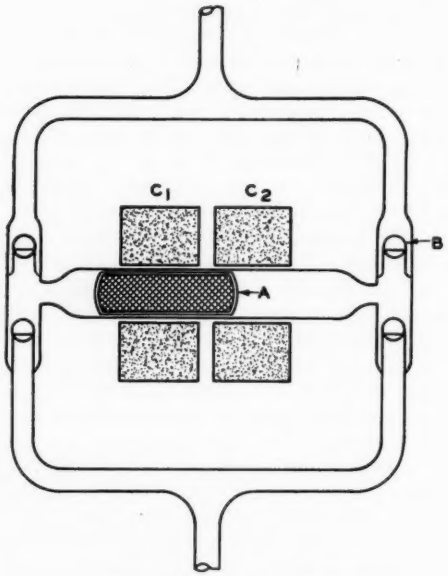


Figure 1. Glass Circulating Pump

A, glass piston with sealed-in iron core; *B*, ball check valve; C_1 and C_2, alternately energized solenoids.

IN PRECISE laboratory investigations where gaseous reactants are recirculated through reaction zones or absorbents, it is important that adequate circulation be maintained without leakage or contamination. Sometimes an apparatus can be designed so that circulation can be developed by suitable heating of an exposed section to produce a thermal syphon effect. However, this arrangement is not always effective, particularly if some component of the circulating system offers appreciable resistance to gas flow. Several types of magnetically-operated circulating pump constructed either of metal[1] or glass[2] have been described in the literature. From the standpoint of freedom from contamination, leakage, or corrosion problems, an all-glass pump that can be sealed directly into the apparatus is usually the most desirable. The glass pump described here was designed and built in our laboratory, and has given excellent service in an apparatus for investigating the reducibility of metal oxides with hydrogen.

The construction of the pump is indicated by Figure 1. The cylinder and piston, *A*, were adapted from a Pyrex, 5-ml. hypodermic syringe. A bundle of soft iron wire was sealed within the glass piston which is moved back and forth inside the cylinder by alternately energizing the two solenoids C_1 and C_2. The arrangement of the four spherically-ground check valves *B* makes pumping action effective with each movement of the piston. The inlet and outlet lines are of 6-mm. outside diameter Pyrex tubing, and the over-all dimensions are about $4^1/_2 \times 4^1/_2$ in. The pump is operated with the cylinder in a horizontal position, whereas the valve compartments are vertical. The coils C_1 and C_2 are $^{13}/_{16} \times 2$ in., and are wound with approximately 3000 turns of 30-gage, enameled copper wire.

A power supply was constructed to provide direct current for alternately energizing the two solenoids. The power supply employs a type-6X4 rectifying tube, and delivers approximately 65 milliamperes at 200 volts d. c. in normal operation. The details are shown in Figure 2. The power is applied alternately to each coil by means of a single-pole, double-throw microswitch operated by a cam rotating at 60 r. p. m.

The pump will operate against a back pressure of about 20 millimeters of mercury and delivers from 150 to 200 milliliters of air at normal temperature and pressure. During continuous use it may be desirable to provide an air jet for cooling the coils and pump cylinder, but this is not necessary for intermittent operation.

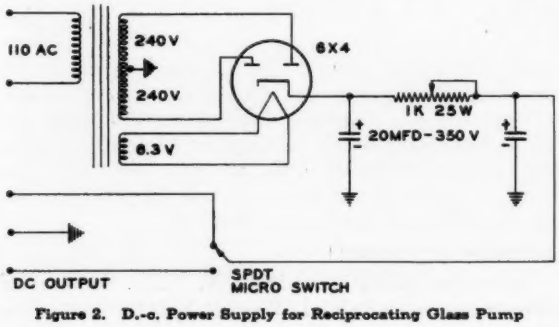


Figure 2. D.-c. Power Supply for Reciprocating Glass Pump

ACKNOWLEDGMENT

The authors acknowledge the assistance of W. C. Hahn, who was responsible for the design and construction of the power supply and the solenoids. Acknowledgment is also made to the Phillips Petroleum Company for permission to publish this article.

[1] ROSEN, *Rev. Sci. Instr.*, **24**, 1061 (1953).

[2] PORTER, BARDWELL, AND LIND, *Ind. Eng. Chem.*, **18**, 1086 (1926); FUNNELL AND HOOVER, *J. Phys. Chem.*, **31**, 1099 (1927); LIVINGSTON, *ibid.*, **33**, 955 (1929); WILSON, OTVOS, STEVENSON, AND WAGNER, *Ind. Eng. Chem.*, **45**, 1480 (1953).

BATCH DISTILLATION

J. P. W. HOUTMAN and ASGHAR HUSAIN
University of Indonesia, Bandung, Indonesia

In view of the importance and usefulness of educational training in batch distillation, a scheme has been presented consisting of (1) a simple method for predicting distillation conditions for a desired separation, and (2) the procedure for checking the results with simple apparatus in the laboratory.

The importance of practical training in the operation of distillation columns as part of chemical engineering education cannot be overemphasized. On the other hand, it is quite a problem to develop some suitable kind of equipment with full features to give the student an insight into this important unit operation.

Most laboratories use continuous columns because of constancy in compositions of the feed, top, and bottom streams, to enable the students to make simple calculations. Such an apparatus, however, requires provision for the distillation of different mixtures under various conditions; and such columns may not be easily available in every laboratory.

It is much easier to construct batch-type columns. A simple glass column provided with an electrically heated jacket, a condensation head, and a valve for product take-off will be available in most laboratories. It only requires an adequate arrangement for the measurement of reflux ratio and for adiabatic operation. Constantly changing concentrations of the top and bottom products in these columns offer opportunities for the students to study various conditions of operation encountered during the course of distillation.

Further, training with the batch columns seems to be quite fruitful, particularly in the technically less advanced countries where this practice will be more common in industry.

In order to conduct this training in accordance with the considerations in industry, it may be useful to let the students work on a scheme as follows:

(*a*) Calculation of the conditions necessary to separate a first distillate fraction out of a given binary mixture so that certain purity and yield of lower-boiling component are obtained. Requirements for the purity and yield can be chosen so as to correspond with other parts of the scheme, *i. e.*, possibility of subsequent checking in the laboratory.

(*b*) Checking of part (*a*) by calculation of a theoretical distillation curve on the basis of the results obtained, using Rayleigh's equation (*7*, *10*).

(*c*) Determination of the actual distillation curve working under the calculated conditions.

Afterward, average composition of the fraction under consideration can be deduced from both theoretical and experimental curves and compared with the desired one.

CALCULATION OF OPERATING CONDITIONS

The operating conditions which influence the shape of a distillation curve or, in other words, the requirements for purity and yield of lower-boiling component, are reflux ratio, number of plates, and ratio of column holdup to charge. For the case where holdup is not negligible compared to the charge, calculation of these conditions will be one of trial and error, as only a reverse calculation of the curve from the known conditions is possible by a direct method (*8*).

If the effect of holdup is assumed to be negligible,[1] direct solution is possible only when development of the actual curve in the region of the desired fraction is known; otherwise a trial and error method has to be used. In order to avoid this, a simple assumption can be made: The part of the distillation curve representing the desired fraction is a completely horizontal line. In fact, the actual curve will develop partly above and partly below this horizontal line. However, such an assumption makes it possible to select a certain point on this line, which represents a combination of the bottom liquid and dsitillate compositions to be used as basis for calculation. Then the reflux ratio and number of plates can easily be found using McCabe-Thiele's graphical method (*4*).

Regarding the proper selection of the reference point, it must be kept in mind that only one point on the horizontal line can provide proper conditions. As its location will be related to the shape of the curve, a choice based on requirements alone will lead to deviations in the results. Therefore, for lack of sufficient information about the best point to give a minimum deviation, the end point of the horizontal line can be used for calculation; it will provide a maximum difference between top and bottom concentrations, consequently facilitating construction of McCabe-Thiele's diagram.

When the holdup is negligible or its effect is beneficial for the separation, the method of calculation outlined above will, in most cases, provide distillation conditions producing better results than required. Anyhow, in practice once the column is designed and constructed there always exists the possibility of adjusting to a smaller reflux ratio with benefit of greater production. Such an adjustment will not much disturb the economics of operation. In some cases holdup can be detrimental for the separations (*9*, *11*), which may possibly offset the advantageous effect gained by using the calculation method described.

[1] Batch distillation is mostly carried out in packed columns, which can be selected so that the holdup is under five per cent of the charge, for which the effect of holdup is reported as negligible (*9*).

Example. A mixture of carbon tetrachloride and benzene having an initial composition of 50 mole per cent, must produce a first distillate fraction with an average composition of 65.5 mole per cent carbon tetrachloride and a yield of carbon tetrachloride equal to 80 per cent of its amount originally present in the charge.

Out of the above requirements the amount of the desired fraction can be calculated as being $(50 \times 0.8)/0.655 = 61.07$ per cent of the charge. At the end of this fraction the bottom composition will be $(100 \times 0.5 - 50 \times 0.8)/(100 - 61.07) = 0.257$ mole fraction of carbon tetrachloride.

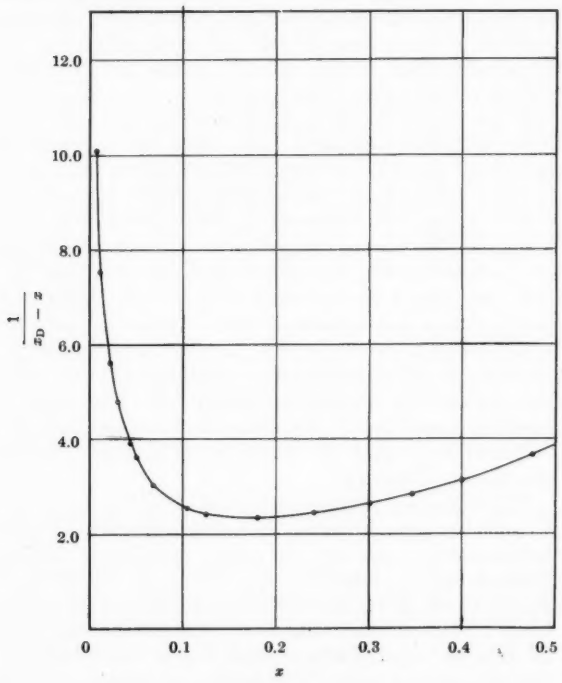


Figure 1

Now this calculated bottom composition (25.7 mole per cent carbon tetrachloride) can be combined with the desired average composition of the fraction (65.5 mole per cent carbon tetrachloride). With these values and using McCabe-Thiele's method, it is possible to choose a proper combination of the reflux ratio and number of plates which will give the most economical operation (*1, 6, 9*). In a laboratory experiment using a column available in the laboratory, it is only a question of selecting the proper reflux ratio.

CALCULATION OF DISTILLATION CURVE

As mentioned before, this part of the scheme has been introduced to give the students an opportunity for checking their results obtained under (*a*), as well as acquiring some practice in calculating the distillation curve. For this purpose Rayleigh's equation (*7, 10*) can be used:

$$\ln M/M_o = \int_{x_o}^{x} dx/(x_D - x)$$

where M_o = moles of charge, M = moles left in the bottom at any moment, x_o = mole fraction of more volatile in M_o, x = mole fraction of more volatile in M, x_D = mole fraction of more volatile in the distillate.

The integral in the above equation has to be solved graphically, for a plot is required between x and $1/(x_D - x)$ (Figure 1). To prepare such a graph, values of x for particular values of x_D can be found by using the equilibrium curve and McCabe-Thiele's method, together with the number of theoretical plates and the reflux ratio calculated under (*a*). It will result in parallel operating lines all originating from x_D values lower than the one corresponding to the composition of the initial mixture. When values of x_D are small it is difficult to draw the proper number of plates on the diagram; in such cases intersection of the operating line with the equilibrium curve will give the value of x for a certain value of x_D. Thus, from the values of M/M_o obtained from Rayleigh's equation, percentage distilled $[(M_o - M)/M_o \cdot 100]$ may be plotted versus composition of the distillate, x_D, which is the required curve.

EXPERIMENTAL CHECK

Checking of the calculated curve can be done in a simple distillation column which has a holdup of less than 5 per cent of the charge. Among all glass columns commonly used in most laboratories, the Vigreux type has the lowest holdup.

Adiabatic operation can be approximated by using a jacket around the column, provided with an electrically heated wound metal coil hanging freely in the space between.[2] Heat losses can be tested by doing an experiment at zero reflux, and comparing the composition of the distillate thus obtained with that of the vapor in equilibrium with the bottom liquid; in this manner the necessary temperature difference between the jacket and condenser can be determined.

Another problem concerns measurement of the reflux ratio. The simplest way is to count drops of the reflux and the distillate falling from extended glass tubes. The volume of the drop is directly related to the shape of the tube, surface tension of the liquid, rate of formation of the drops, and the pattern of liquid flow in the tube. If tubes of equal diameters and with oblique ends are used, the ratio of drop volumes remains approximately constant for different compositions of the liquid, provided that the rates of falling at both sides are kept constant, the temperatures of the liquid from both tubes are the same, and the tubes are not completely filled with liquid (*3*). A preliminary determination of the relationship between drop volume

[2] A better arrangement can be obtained by winding a metal coil on an extra glass tube using asbestos strips, and inserting this tube between the column and the outer jacket.

and falling rate with a certain liquid for each glass tube will be sufficient for the measurement of the reflux ratio.

EXPERIMENTAL PROCEDURE AND RESULTS

An all-glass Vigreux column provided with a total condensation head and an electrically heated jacket and flask was used.

Column inside diameter, mm.	18
Column length, cm.	236
Number of theoretical plates (determined at total reflux)	20 ± 1
Average boil up rate, moles/min.	0.03
Average estimated holdup, moles	0.11

The number of theoretical plates in the column was determined at total reflux,[3] using a mixture of benzene and ethylene dichloride, and also a mixture of carbon tetrachloride and benzene. Components were purified in the same column at a reflux ratio of 10:1 starting with technically pure liquids.[4] Refractive indexes of the pure liquids were measured with a Zeiss Opton type of Abbe-refractometer[5] at 35°C. (The values n_D^{35} are for benzene 1.4918; CCl_4 1.4517; $C_2H_2Cl_2$ 1.4372.)

For the mixture of benzene and ethylene dichloride, equilibrium data by Pahlavouni (*5*) were used, and for the mixture of carbon tetrachloride and benzene, data by Bushmakin and Voyeikova (*2*).[6]

Average Composition and Yield of the First Distillate Fraction

	Composition mole % carbon tetrachloride			*Yield carbon tetrachloride mole %*			*Starting holdup mole %*
	Req.	*Calc.*	*Exp.*	*Req.*	*Calc.*	*Exp.*	
1	65.5	70.9	71.1	80.0	86.6	86.9	4.6
2	65.5	70.9	69.7	80.0	86.6	85.2	4.2
3	65.5	70.9	70.5	80.0	86.6	86.2	5.3
4	65.5	70.9	71.1	80.0	86.6	86.9	4.2
5	65.5	70.9	70.4	80.0	86.6	86.0	4.6
6	65.5	70.9	71.2	80.0	86.6	87.0	4.1
7	65.5	70.9	70.4	80.0	86.6	86.0	4.8
8	65.5	70.9	70.4	80.0	86.6	86.0	4.2

Using the determined number of theoretical plates, the necessary reflux ratio was calculated for the desired separation as outlined in the example, and was found to be nearly 40:1. Then the theoretical distillation curve was calculated, using Rayleigh's equation. Figure 1 shows the curve of x versus $1/(x_D - x)$ used for this calculation.

Finally, the experimental curve was determined, starting with about 250 ml. of liquid having an initial composition of 50 mole per cent carbon tetrachloride and distilling up to 85 mole per cent of the charge. In each case the column was run for some time at total reflux. Then the fractions were drawn at regular intervals of time at a reflux ratio of 40:1, and were analyzed by measuring refractive indexes. Figure 2 shows the experimental curve of run No. 1, superimposed on the theoretical curve.

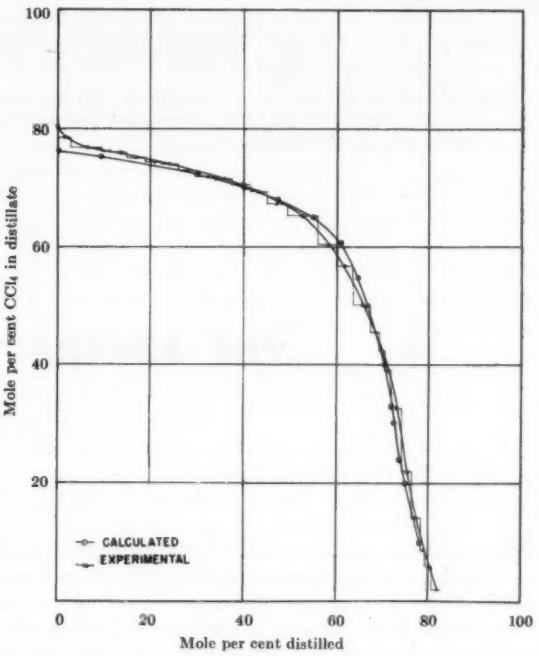


Figure 2

From the experimental curve the average composition of the fraction amounting to 61.07 mole per cent of the charge was calculated. Results of different runs are compared in the table with those from the theoretical curve, and also with the predetermined requirements.

CONCLUSIONS

The reasonable agreement found in the results indicates that the scheme, besides being of special interest for training purposes, also suggests a simple method for calculating column properties and reflux ratio in industrial applications. However, more details are required to test the usefulness of this method, particularly when sharper separations are desired using smaller reflux ratios.

Further, compared with the direct calculation method suggested recently by Zuiderweg (*11*), the method presented in this paper, in spite of its limitations, possesses the advantages that (1) it can be applied in all cases including those when relative volatility cannot be accepted as constant, and (2) no relation is needed be-

[3] Before samples were drawn from top and bottom, the jacket temperature was regulated to within three degrees below that of the condenser. Sufficient time was allowed for establishment of equilibrium conditions.

[4] Before purification in the column, benzene was shaken with concentrated sulfuric acid, diluted alkali, and water, and finally dried over calcium chloride.

[5] Checked with molecular-weight benzene extra purified by freezing (refractive index $n_D^{35} = 1.4918$).

[6] These data are the same as those reported by Perry (*6*).

tween the amount of intermediate fraction and "pole height," the latter being used as a criterion for characteristic of the curve.

LITERATURE CITED

(1) BADGER, W. L., AND W. L. MCCABE, "Elements of Chemical Engineering," 2nd ed., McGraw-Hill Book Co., Inc., New York, 1936, p. 365.
(2) BUSHMAKIN, I. N., AND E. D. VOYEIKOVA, *J. Gen. Chem. USSR.*, (English Translation, Consultant Bureau, New York) **19**, a35–a48 (1949).
(3) HOUTMAN, J. P. W., *Chem. Weekblad*, **41**, 75–9 (1945).
(4) MCCABE, W. L., AND F. W. THIELE, *Ind. Eng. Chem.*, **17**, 605–11 (1925).
(5) PAHLAVOUNI, F., *Bull. Soc. Chim. Belg.*, **36**, 533–47 (1927).
(6) PERRY, J. H., "Chemical Engineers' Handbook," 3rd ed., McGraw-Hill Book Co., Inc., New York, 1950, p. 593.
(7) RAYLEIGH, LORD, *Phil. Mag.*, **8**, 534 (1904).
(8) ROSE, A., ET AL., *Ind. Eng. Chem.*, **42**, 2145–9, 2494–7 (1950); **43**, 2459–64, 2502–6 (1951).
(9) ROSE, A., ET AL., *Chem. Eng. Progr.*, **48**, 549–56 (1952).
(10) SMOKER, E. H., AND A. ROSE, *Trans. Am. Inst. Chem. Eng.*, **36**, 285–93 (1940).
(11) ZUIDERWEG, F. J., *Chem. Ing. Tech.*, **25**, 297–307 (1953).

THE ABSTRACT OF THE TECHNICAL REPORT

ETHALINE CORTELYOU
Illinois Institute of Technology, Chicago, Illinois

MY OPINIONS on abstracts of technical reports are based chiefly on my five years of experience as a technical editor at Armour Research Foundation. The Foundation does research under contract for government agencies and industrial organizations, and the sponsor of each contract is kept informed of the progress of his research project by means of periodic technical reports. The Foundation usually has 500 current projects, so we process from 2000 to 3000 technical reports a year.

In general, two types of abstract section of technical reports are recognized: the descriptive and the informative. The descriptive abstract may be nothing more or less than the table of contents written in sentence form. An informative abstract will briefly state the problem, the method of conducting the investigation, the conclusions reached, and the recommendations made. The informative summary, of not more than one page, is the type preferred at Armour Research Foundation. A model ARF abstract contains a statement of the objective of the research and is a synopsis of the body of the report with emphasis on the results, conclusions, and recommendations.

Sometimes the abstract of a technical report may be referred to as a synopsis, a summary, or an epitome. However, even though an abstract may be called a summary, it should not be confused with the concluding summary sometimes placed at the end of a report. A concluding summary brings the report to a logical and obvious ending on the basis of the over-all discussion of results, conclusions, and recommendations.

There are two fundamental differences between an abstract and a summary:

(1) The abstract is written in narrative form, and the summary is written in expository or even argumentative form.

(2) The abstract is complete in itself while the summary depends upon the discussion in the report.

The abstract merely narrates the main points of a report. The summary explains the logic of the conclusions and the recommendations for future work. As such, the summary cannot be read out of context because it is dependent upon the rest of the report. It is written in a manner designed to convince or persuade the reader that the conclusions reached are the logical interpretation of the data.

In editing reports one can usually recognize the neophyte writer by his abstracts. Either he writes a purely descriptive abstract or he lifts whole sentences bodily from the report and repeats them in his abstract. Sometimes at the Foundation the descriptive abstract is the result of an effort to stay within the preferred one-page limit. Obviously it is almost impossible to write an informative one-page abstract of a report of 300 or more pages, so abstracts for very long reports are exceptions to the rule.

The other practice of the neophyte, copying sections verbatim from the report, is perhaps as good a way as any to write the *first draft* of an abstract. But succeeding revisions and drafts should be greater and greater condensations until the final draft is an abstract containing only one to five per cent as many words as the report, itself, certainly not more than 10 per cent. After all, too long an abstract defeats the purpose of writing one at all.

[1] Presented before the Division of Chemical Literature at the 127th Meeting of the American Chemical Society, Cincinnati, March, 1955.

And that brings up a point that might have been used to start this discussion: What is the purpose of writing an abstract? Perhaps this can best be answered by considering who reads abstracts and why.

At the Foundation we say the abstract of a report is designed primarily to inform management, and we back this up by routinely sending only the abstract (without the report) to our top administration. Probably neither Foundation management nor a sponsor's management can take the time to read a 300-page final report, yet both want to know the results and the recommendations. Foundation management needs to be reminded of the objective of the research and, being scientific, wants to be informed briefly what methods were used to solve the problem.

Actually, the Foundation type of abstract will also meet the needs of the busy scientist who skims the abstract to determine whether a report contains enough of interest in his research for him to take the time to read the entire report.

It seems to me that there is now a third and very important type of abstract reader who should be considered in writing a report abstract—the librarian. Fortunately, the traditional librarian, the custodian of books, is being replaced by a new type of librarian, one who recognizes that her job is not counting books but is getting them into the hands of those who need them. To indicate this trend from book storage to book referral there is an increasing use of the terms "information service" and "information specialist" (or information officer) to replace the words library and librarian. This trend is particularly apparent in the document or report libraries where the documents or reports are often unpublished in the sense that distribution may be restricted and that the total number of existing copies of any one report may be counted in the dozens rather than the thousands.

Although the information specialist probably has some scientific background, she cannot hope to understand all the reports that come to her for cataloguing and referral. It is obvious that if a report is catalogued under the wrong subject headings it may never be found by the people who need it. Actually there is less danger of wrong cataloguing from an abstract than of incomplete cataloguing. So it is important that an abstract should contain the pertinent information stressed in the report itself. As Jeanne North[2] said:

> The abstract will become even more important if the trend toward catch-word cataloguing continues. In Dr. Mortimer Taube's system for library cataloguing, the subject headings to represent a report in the card catalogue are to be chosen from the important words noted in the abstract. This streamlined procedure puts the burden of adequately covering the subject matter and applications of a report squarely on the abstractor.

And that brings us to the question: Who should write the abstract? Everyone agrees that the abstract should be the very last part of the report written, but there are two schools of thought as to who should write it. Some recommend that the abstract should be written by someone other than the author of the report. Usually they recommend that the author's supervisor write the abstract so that he will make a more critical scientific evaluation of the report. In my own experience this results in a delay of anywhere from two days to three weeks, depending on the supervisor and often, alas, on how late the report is when it reaches him. It seems to me that the same goal can be achieved relatively painlessly by asking the supervisor to reread the abstract after he has read the report to determine whether:

(1) The report covers all the items mentioned in the abstract;

(2) The abstract and the report are in agreement as to the relative importance of items of information; for instance, the points stressed in the report are also stressed in the abstract;

(3) The abstract is as brief as feasible.

These three check points are adapted from some suggested by Gray.[3]

The abstract is actually the most difficult part of the report to write because it must cover all the salient points of the report concisely. The report writer is best prepared to write the abstract of his own report. He knows the novelty of his equipment or procedure, the most important data he reported, and the importance of his conclusions and recommendations. If the supervisor critically compares the report and the abstract according to the three check points given, the desired critical scientific evaluation of the report is achieved in one-tenth the time it would take him to write the abstract. After all, the abstract of the report is not a disciplinary exercise to make sure the supervisor does his job in the most time-consuming way possible. Certainly the writer may find it difficult to judge his report objectively when he writes his abstract, but the supervisor and even the editor can supply that objectivity when comparing the abstract with the report.

Of course, there is the compromise of having both the author and the supervisor write abstracts. The supervisor would then read the report and write his own abstract before reading the author's abstract. This compromise, like most compromises, is unsatisfactory. It does not save time, but rather requires more time. It, too, resembles schoolroom discipline. In addition, there is the problem of deciding between two pieces of writing, and no father can be more proud and protective of his offspring than an author can be of his writing.

In some respects, the technical report writer should follow the advice of the old-time preacher who said: "First I tell them what I am going to tell them, then I tell them, and then I tell them what I've told them," by using the abstract, the body of the report, and the summary for his three tellings.

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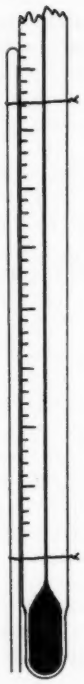
[2] NORTH, J. B., "Editing: stumbling block or stepping stone?" Paper presented before Technical Writers and Editors Session, American Documentation Institute, Cleveland, November 5, 1954.

[3] GRAY, DWIGHT E., "How readable is your technical report?" J. CHEM. EDUC., 26, 374–6 (1949).

A SIMPLE CHARLES' LAW EXPERIMENT

V. R. DAMERELL
Western Reserve University, Cleveland, Ohio



Some time ago the writer devised a Charles' law experiment suitable for general chemistry classes; this has since been used and improved in the writer's own classes for the past several semesters. The experiment is new, to the writer's best knowledge; it is sufficiently accurate, and it is easier to carry out than any other experiment used to verify Charles' law that is familiar to the writer. Because of its simplicity the method is presented here for possible consideration by other chemistry teachers.

The basis for the experiment is the fact that in a narrow tube, where the ratio of length to diameter is 50 or more to one, the length of the tube is virtually proportional to the volume of gas in the tube. Furthermore, as a cooling specimen of gas sucks a column of liquid into such a tube, the changing length of the gas column is not only proportional to the changing gas volume, but the inner meniscus of the liquid enables that length to be measured. A ratio of gas-column lengths can then be substituted for the usual ratio of gas volumes in the Charles' law equation. This permits the following experiment.

A 10-cm. portion (or longer) of small-bore glass tubing is sealed at one end and fastened to a thermometer, open end down, with two pieces of string or pliable wire, as shown in the illustration. The students can work individually or in groups as they remove sections of tubing from longer pieces, seal one end in a flame, and fasten the sections to thermometers. Meanwhile an oil bath is prepared for class use. This is conveniently a large beaker containing a good grade of motor oil which will have only a small vapor pressure at, say, 100°C. The depth of the bath must be sufficient completely to cover the tubes attached to the thermometers. The temperature of the bath should be constant, or very slowly rising. With an 800-ml. beaker of oil this last condition is easily met by use of a hot plate, or by warming the oil with a brisk flame and then cutting down the flame to small size.

The students now put the thermometers with attached tubes into the oil bath and leave them until their thermometers register the same temperature as the bath thermometer, at which time it is assumed that the gas column in the tube is also at bath temperature. The bottom, open end of the tube is now examined through the side of the beaker. Any projecting air bubble is shaken off, since it is important that the air column extend only to the end of the tube.

The temperature is now recorded, and the thermometer is lifted part way from the oil bath, but not yet far enough so that the open end of the tube comes out of the oil. This step is to allow the tube to cool so that oil begins to enter. In a few seconds, when an oil column a few millimeters in length has entered the tube, the thermometer and attached tube are taken out of the bath, placed horizontally on any convenient surface, and allowed to cool to room temperature. The inner meniscus of the little oil column now marks the end of the contracting gas column.

When the thermometer shows room temperature the gas column is assumed to be at the same temperature. A milliliter rule is now used to measure (*a*) the inside length of the entire tube, and (*b*) the length from the inside of the closed end to the oil meniscus. Measurement (*a*) is the length of the gas column at bath temperature, while measurement (*b*) is the gas-column length at room temperature. These measurements, together with the two temperatures, comprise the data. Two sets of experimental results which are typical are shown below:

	Experiment A	*Experiment B*
Air-column length at 96°C. (Inside length of entire tube)	109 mm.	105 mm.
Air-column length at 24°C. (From closed end to oil meniscus)	88 mm.	85.5 mm.

Various calculations can be made from this data. The version of Charles' law which applies here is:

$$\frac{\text{Air-column length I}}{\text{Air-column length II}} = \frac{\text{Absolute temperature I}}{\text{Absolute temperature II}}$$

These two ratios can be calculated and compared.

$$\frac{109}{88} = 1.24; \qquad \frac{105}{85.5} = 1.23; \qquad \frac{(96 + 273)}{(24 + 273)} = 1.24$$

Results like these, accurate to about one per cent, can readily be obtained by students. The accuracy is undoubtedly aided by the fact that the two errors caused by hydrostatic pressure of the oil and vapor pressure of the oil are in opposite directions, and hence tend to nullify each other. In another calculation the length of the air column at room temperature can be computed and compared to the observed length. Still another possibility is to calculate absolute zero on the centigrade scale. Thus:

$$\frac{109}{88} = \frac{96 + X}{24 + X}$$

and $-X$ will be what the student finds for absolute

zero on the centigrade scale (−278°C. in this experiment). Of the various possible calculations students perhaps find this one the most interesting.

The bath must not be too hot, because the oil vapor pressure then becomes significant. At 140°C., for example, results were poor. A solvent-extracted neutral oil with a viscosity of 300 (SUV) at 100°F. was in the bath.

$$\frac{103.5}{68.5} = 1.51; \qquad \frac{140 + 273}{25 + 273} = 1.39$$

The experiment has been described here as it would be done by general chemistry students. Refinements beyond this are, of course, possible and some instructors may wish to make small corrections for hydrostatic pressure of the oil, for oil vapor pressure, for the exposed stem of the thermometer, etc. Stirring and thermostatting of the oil bath may also be preferred. In the absence of these refinements the students can still get a satisfactory verification of Charles' law, performing the experiment in the simple manner described.

NUMERICAL INTEGRATION: A TOOL FOR CHEMICAL ENGINEERS

JOHN L. GIDLEY
Humble Oil & Refining Company, Austin, Texas
HOWARD F. RASE
University of Texas, Austin, Texas

In chemical engineering calculations such as the determination of the number of transfer units or the calculation of reactor volume, the evaluation of a definite integral is required. For many such integrals, actual analytical integration is not possible because of the complex relations between variables. In such instances the chemical engineer usually resorts to graphical integration. Such integration is straightforward and easily understood. It involves the calculation of several values of the function to be integrated. These values are then plotted on a suitable graph, the best curve is drawn through them, and the area under the curve is determined by the use of a planimeter, by an approximation with trapezoids, or by the method of counting squares.

An equally legitimate but less common procedure is to evaluate this integral numerically. The purpose of this article is to show that a numerical integration, in general, involves fewer steps than a graphical integration, requires less time, and frequently is more accurate.

The procedure involved in a numerical integration is as follows. To evaluate:

$$\int_a^b f(x)dx \qquad (1)$$

where $f(x)$ is either very complicated analytically or is known only through its numerical values at several points, $f(x)$ is replaced by $\phi(x)$, where $\phi(x)$ is some simple (easily integrated) function which may be fitted readily to the numerical values, and the integration is performed analytically. Most conveniently $\phi(x)$ will be some polynomial in x of the general type:

$$a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots a_nx^n \qquad (2)$$

because of the ease with which it may be integrated. Fortunately, several interpolation formulas are of this simple form, and are at the same time easily fitted to numerical values. For this reason they are ideally suited to the problem at hand. After the interpolation formula $\phi(x)$ is chosen, it is fitted to the points and is integrated analytically to obtain an approximate evaluation of the integral of the original function, $f(x)$.

The limitations of this procedure were examined critically by the eminent mathematician Weierstrass in 1885. His analysis resulted in the famous Weierstrass approximation theorem which states that, "A continuous function may be approximated over a given interval by a polynomial to any assigned degree of accuracy."[1] While only continuous, nonperiodic functions may be approached in this manner (periodic functions require a different approach), a sufficiently large majority of chemical engineering calculations involve such functions to make further consideration of this procedure worth while.

If it were necessary to follow the complete procedure indicated above each time a numerical integration was to be performed, the process would indeed seem un-

[1] James, G., and R. C. James, Editors, "Mathematics Dictionary," D. Van Nostrand Company, Inc., New York, 1949, p. 380.

attractive. Fortunately, a general integration of each of the more important interpolation formulas, such as Newton's, Stirling's, and Bessel's, has been made, and only the final results need to be considered here. For the details of these integrations, Scarborough's "Numerical Mathematical Analysis"[2] should be consulted.

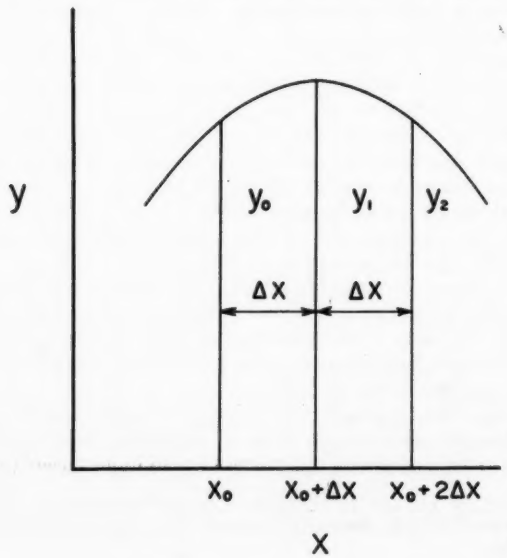
The simplest, and therefore most easily applied numerical integration formulas result from an integration of Newton's interpolation formula. Newton's formula consists of an infinite series of difference terms of ascending order. To make it useful for practical calculations it is necessary to neglect all terms past a certain order; but because this series converges rapidly under the proper conditions, the neglecting of these terms generally does not introduce an intolerable error into the calculations. Formulas may therefore be derived by omitting from this series all terms higher than second order, third order, or some higher order. An investigation of a large number of such formulas has shown that two of the most useful equations result from the neglect of terms past second order and past sixth order. These two formulas are particularly simple because in their final form they contain coefficients which are small integers.

The first of these equations is the well known Simpson's rule which may be written as follows:

$$\int_{x_0}^{x_0 + 2\Delta x} y dx = \frac{\Delta x}{3}(y_0 + 4y_1 + y_2) \qquad (3)$$

The figure indicates the meaning of the symbols that are used. All differences higher than second order are omitted in the derivation of this equation. This is equivalent to fitting the calculated points to a second-degree polynomial, or more specifically, fitting to a parabola with a vertical axis.

[2] SCARBOROUGH, J. B., "Numerical Mathematical Analysis," 2nd ed., The Johns Hopkins Press, Baltimore, 1950, pp. 128–37.



The second equation, which is usually the more accurate, is Weddle's rule. It may be written as follows:

$$\int_{x_0}^{x_0 + 6\Delta x} y dx = \frac{3\Delta x}{10}(y_0 + 5y_1 + y_2 + 6y_3 + y_4 + 5y_5 + y_6) \qquad (4)$$

In the derivation of Weddle's rule, all differences higher than sixth order are omitted; the calculated points are thus fitted to a sixth-degree polynomial.

Both of these equations are of the form:

$$\int_{x_0}^{x_0 + n\Delta x} y dx = a\Delta x\left(\sum_0^n C_n y_n\right) \qquad (5)$$

where the coefficient a depends on the formula chosen, and coefficients C depend both on the formula and on the particular y-value to be multiplied. When more than n increments, corresponding to $(n + 1)$ points, are to be used, the interval must be divided into an even multiple of n increments, and the formulas above must be applied successively to each set of n increments until all points have been included in the integration. This principle is illustrated in the example problem.

The choice between Simpson's and Weddle's rule depends partly on the accuracy desired in the final result and partly on the arrangement of the calculations. The chief limitation of both formulas is that they require equal separation of the points of the independent variable (y values taken at equal increments of x). This is a limitation which is inherent in the derivation of Newton's formula, but it makes possible the simple form of the equations given.

Even though equal separation of three successive points is required by Simpson's rule and seven equally spaced points are required by Weddle's rule, the same spacing need not be used over the entire range of integration. Frequently the function to be integrated will change rapidly in a certain region and more slowly in another. To obtain a worth-while answer to this case it is necessary to take small increments of x through the region of rapid change, while larger increments may be taken in the region of slower change. Any previous knowledge of the function to be integrated may be used to arrange the calculations in an order such that the most worth-while result may be obtained with the least expenditure of effort. This principle, also, is illustrated in the example problem.

The following steps are involved in a numerical integration by Simpson's rule:

(1) Values of the function are calculated at equal intervals of the independent variable. Each set of three successive points, y_0, y_1, y_2, must be separated by a common difference, Δx_I; subsequent sets of points, y_2, y_3, y_4, may be separated by another common difference, Δx_{II}.

(2) The y-values for each set are multiplied by the internal coefficients (coefficients within the parentheses) given by equation (3). These values are then summed to give $1y_0 + 4y_1 + 1y_2$, for the Δx_I set; $1y_2 + 4y_3 + 1y_4$, for the Δx_{II} set, etc.

(3) Each of these sets is then multiplied by its

external coefficient, consisting of the common difference of the set Δx, and its multiplier $^1/_3$, giving the following groups:

$$\frac{\Delta x_I}{3}(y_0 + 4y_1 + y_2);\ \frac{\Delta x_{II}}{3}(y_2 + 4y_3 + y_4);\ \ldots$$

(4) The sum of all such groups gives the value of the integral.

In general, the more sets by which the curve is divided, the more accurate the final result; but a balance must be obtained between the desired accuracy and the amount of time available for calculation.

Computation by Weddle's rule follows the same procedure, but the set consists of seven successive points, and step 2 involves multiplication by the internal coefficients 1, 5, 1, 6, 1, 5, 1, in that order given by equation (4). Step 3 in this case involves multiplication by external coefficients of the type $3\Delta x_I/10$, $3\Delta x_{II}/10$, rather than those given in the outline above.

In a comparison of numerical integration with graphical integration, it should be apparent that the calculation of the ordinates of the curve (step 1 above) is common to both methods. Following this, however, numerical integration substitutes two multiplications and two additions, steps 2, 3, and 4, for plotting the calculated points and determining the area under the curve. These additions and multiplications, which involve small numbers, will almost always require less time and effort than plotting a curve and determining its area; and, if the proper number of points has been chosen, the result obtained by a numerical integration will almost surely be the more reliable one.

EXAMPLE

The following example illustrates the application of both Simpson's and Weddle's rules to a typical problem. This example was adapted from Hougen and Watson's "Chemical Process Principles," Part 3, Kinetics and Catalysis, Illustration 1.[3] For the complete details of the problem, this should be consulted.

Briefly, the problem involves the nitration of benzene with mixed acid and requires the evaluation of the following integral to determine the volume of the required reactor:

$$V_\tau = -\int \frac{dn_B}{r}$$

where V = total required volume of mixture, ft.^{3}; τ = time elapsed during conversion, hr.; n_B = moles of benzene per unit mass of original feed; r = rate of reaction, moles of benzene converted per (ft.^{3}) (hr.). The rate of reaction is given by the equation (after the application of several simplifying assumptions):

$$r = 17.01 x_{Aa}\gamma_{Aa}x_{Bb}\ [1 + 62x_{Aa}(x_{Sb})^{(1\ +\ 40x_{Aa})}]$$

where x_{Aa} is the acid concentration in the acid-rich layer; x_{Bb} and x_{Sb} are the benzene and nitrobenzene concentrations in the organic-rich layer, respectively; γ_{Aa} is an empirically determined activity coefficient; x_{Aa}, x_{Bb}, and x_{Sb} are related to n_B by material balances. Since γ_{Aa} is a function of x_{Aa}, it too is a function of n_B. Therefore, r is an implicit function of n_B only, and the integration desired is possible.

To evaluate this integral graphically, values of r must be calculated at various values of n_B. Then $1/r$ is plotted against n_B and the resulting area under the curve is determined. The calculation of $1/r$ as a function of n_B is required, also, in a numerical integration, but the plotting of a curve is not necessary.

Values of $1/r$ at several values of n_B are tabulated below. An inspection of these values will show that as n_B gets very small, *i. e.*, as less unreacted benzene remains and conversion approaches 100 per cent, $1/r$ changes rapidly. This results in a correspondingly rapid increase in reactor volume; hence, to determine the reactor volume within any preassigned range of accuracy, considerably more accuracy is required of the calculations toward the end of the reaction than at the beginning. For this reason, points have been calculated much more closely (at smaller increments of n_B) in the high conversion range than in the low.

The basis for the calculations is 100 moles of benzene at the start of the reaction (*i. e.*, $n_{Bo} = 100$). The calculations, arranged as they were in the original example, employed a common difference of five per cent conversion (= five moles of benzene) between 0 and 90 per cent. The resulting 19 points are easily divided into three sets of seven points each (the two points between the three sets are counted twice) and are readily integrated by three successive applications of Weddle's rule. The first set, for 0–30 per cent conversion, is calculated:

$$V_\tau = -\int_{n_{Bo}}^{n_{Bo}\ +\ 6\Delta n_B} \frac{dn_B}{r} = -\frac{3\Delta n_B}{10}\left(\frac{1}{r_0} + \frac{5}{r_1} + \frac{1}{r_2} + \frac{6}{r_3} + \frac{1}{r_4} + \frac{5}{r_5} + \frac{1}{r_6}\right)$$

Values from the table are substituted in this formula:

$$[V_\tau]_{0 \to 30} = -\int_{100}^{70} \frac{dn_B}{r} = -\frac{3(-5)}{10}$$
$$[0.00540 + 5(0.00588) + 0.00645 + 6(0.00711) + 0.00778 + 5(0.00848) + 0.00935]$$

since $\Delta n_B = 95 - 100 = \ldots = 70 - 75 = -5$. The final result is:

$$[V_\tau]_{0 \to 30} = \frac{15}{10}(0.14344) = 0.2156 \text{ liter-hr.}$$

The next increment is calculated in a similar manner.

It should be stressed that Weddle's rule is used in this region not for any increase in accuracy over Simpson's rule, but rather because the calculations as they were originally made are easily fitted to Weddle's rule, perhaps even more so than to Simpson's rule. Also, it is worth noting that since all 19 points are separated by the same difference, the calculations could have been carried out as a single integration from 0 to 90 per cent by the use of the following coefficients: 1, 5, 1, 6, 1, 5, 2, 5, 1, 6, 1, 5, 2, 5, 1, 6, 1, 5, 1. But if the common

[3] Hougen, O. A., and K. M. Watson, "Chemical Process Principles," John Wiley & Sons, Inc., New York, 1947, pp. 1054–60.

% benzene converted	n_B	$\frac{1}{r}$	Rule used	Internal coefficient, C	$C\left(\frac{1}{r}\right)$	$\Sigma C\left(\frac{1}{r}\right)$	External coefficient: Δn_B	External coefficient: Multiplier	$-\int \frac{dn_B}{r}$
0	100	0.00540		1	0.00540				
5	95	0.00588		5	0.02940				
10	90	0.00645		1	0.00645				
15	85	0.00711	Weddle	6	0.04266	0.14344	5	3/10	0.2152
20	80	0.00778		1	0.00778				
25	75	0.00848		5	0.04240				
30	70	0.00935		1 1	0.00935				
35	65	0.01045		5	0.05225				
40	60	0.01213		1	0.01213				
45	55	0.01370	Weddle	6	0.08220	0.27436	5	3/10	0.4115
50	50	0.01626		1	0.01626				
55	45	0.01695		5	0.08475				
60	40	0.01742		1 1	0.01742				
65	35	0.01770		5	0.08850				
70	30	0.01816		1	0.01816				
75	25	0.01904	Weddle	6	0.11424	0.51132	5	3/10	0.7670
80	20	0.0248		1	0.0248				
85	15	0.0356		5	0.1780				
90	10	0.0702		1 1	0.0702				
92.5	7.5	0.140[a]	Simpson	4	0.560	0.8712	2.5	1/3	0.726
95	5	0.241		1 1	0.241				
96	4	0.352	Simpson	4	1.408	2.214	1.0	1/3	0.738
97	3	0.565		1 1	0.565				
98	2	0.985	Simpson	4	3.940	7.075	1.0	1/3	2.358
99.0	1.0	2.57		1 1	2.57				
99.1	0.9	2.86	Simpson	4	11.44	17.29	0.1	1/3	0.576
99.2	0.8	3.28		1 1	3.28				
99.3	0.7	3.77	Simpson	4	15.08	22.77	0.1	1/3	0.759
99.40	0.60	4.41		1 1	4.41				
99.45	0.55	4.81[a]	Simpson	4	19.24	29.09	0.05	1/3	0.485
99.50	0.50	5.44		1	5.44				
									7.04

[a] Obtained by interpolation between calculated values.

difference for the 30–60 per cent conversion increment had been different from that for either the 0–30 per cent or the 60–90 per cent increment, then the calculations would have had to be performed as three individual integrations.

Simpson's rule is employed for all calculations past the 90 per cent conversion mark. The reason for this is that it requires only three equally spaced points and is therefore more readily fitted to the calculations as they were originally set up by Hougen and Watson. For example, from 90 to 95 per cent conversion, a common difference of 2.5 per cent is employed; from 95 to 99 per cent, a one per cent difference is used, from 99.0 to 99.4 per cent the difference is 0.1 per cent and from 99.4 to 99.5 per cent it is 0.05 per cent.

For the 90 to 95 per cent conversion increment, Simpson's rule is employed as follows:

$$V_T = -\int_{n_B}^{n_B + 2\Delta n_B} \frac{dn_B}{r} = -\frac{\Delta n_B}{3}\left(\frac{1}{r_0} + \frac{4}{r_1} + \frac{1}{r_2}\right)$$

$$[V_T]_{90 \rightarrow 95} = -\int_{10}^{5} \frac{dn_B}{r} = -\frac{(-2.5)}{3}[0.00702 + 4(0.140) + 0.241]$$

since $\Delta n_B = 90 - 92.5 = 92.5 - 95 = -2.5$. Finally:

$$[V_T]_{90 \rightarrow 95} = \frac{2.5}{3}(0.8712) = 0.7257 \text{ liter-hr.}$$

If the calculations are carried out in the above manner, considerably more paper work is used than is required. The table illustrates how the same calculations may be accomplished with considerably less effort. The calculations proceed from left to right as follows: The ordinates $1/r$ in column 3 are multiplied by the internal coefficients in column 5 to get the values of column 6. Column 4 indicates the rule being employed and hence the coefficients to be used. Each bracket encloses the values employed by a single application of the rule. Notice that the end points are used in the two adjacent applications. Column 7 gives the sum of the values in column 6 for the increment given. Column 8 gives the common difference for this increment (the negative sign has been omitted since the final result is positive). The external coefficients required are given in column 9, and the final evaluation of the integral (columns 7, 8, and 9, multiplied together) is given in column 10. The complete integration for the 0–99.5 per cent conversion range is the sum of the values shown in column 10.

The corresponding graphical determination of this integral, because of the vast change in $1/r$ requires the plotting of the data on three separate graphs, each with a different scale. The answer reported for the latter procedure was 7.13, in good agreement with the 7.04 obtained by the numerical integration outlined here.

ACKNOWLEDGMENT

Thanks are due to Professor O. A. Hougen and to John Wiley & Sons, Inc., for giving permission to use the example from "Chemical Process Principles."

WARBURG VESSEL WASHER

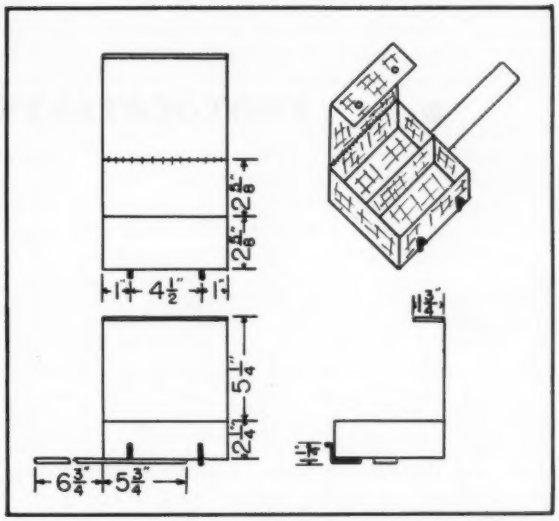
EARL FRIEDEN
Florida State University, Tallahassee, Florida

THE Warburg manometric technique for determining small changes in the volume of a gas phase is widely used in biochemical and clinical research. Washing the specialized glassware used in this technique is a time-consuming chore, particularly when extra precautions are necessary for highly sensitive enzyme work. A single Warburg vessel may be individually handled and drained as many as 15 times in one complete washing. This large amount of treatment also increases the chance of breakage of these expensive, specialized pieces of glassware.

A simple Warburg vessel washer aid may be constructed by a relatively inexperienced technician. Dimensions for such a washer holding 14 ordinary Warburg vessels are given in the accompanying figure. All parts of this gadget are of stainless steel using stainless-steel wire cloth, type No. 304, 1/8-inch mesh, 0.028-inch diameter, $1.30 per square foot,[1] and approximately 18-gage stainless-steel sheet. These will show some discoloration on continual immersion in solutions of hot, concentrated nitric acid, but no extensive decomposition. The discoloration is not believed to contribute significantly to contamination of either vessels or washing solutions.

The stainless-steel handle is attached to the bottom of the vessel container by threading stainless-steel wire through the partition and tying these wires to the handle. The handle is bent in the long axis to form a curved surface more comfortable to handling. The partition is also wired to the sides for reasonable rigidity. Two braids of stainless-steel wire, attached to a side and the bottom of the basket, are used to lock the basket lid by insertion through holes in the descending part of the lid. All exposed edges of the wire cloth are bent over and sewed to the adjoining side in order to eliminate sharp edges. The lid is wired on using several loose wirings with stainless-steel thread as hinges.

Once the vessels are locked in the basket, the entire container may be immersed with impunity in such diverse solvents as petroleum ether, hot, concentrated nitric acid, as well as all aqueous solutions. Rinsing solutions may be introduced directly through the pores of the wire cloth. It has been estimated that the use of this simple washer aid reduces the time required for washing to one-third to one-half the time required by other methods. After rinsing, the vessels can be dried in an oven in an upside-down or other desirable draining position. Thus, for 14 vessels, the number of individual vessel handlings can be reduced from 210 to about 28.



It is obvious that similar problems related to cleaning other specialized glass equipment may be solved by custom-made equipment designed as described in this communication. We have found it very convenient to use stainless-steel wire-cloth baskets for drying and storing small glassware such as pipets, volumetric flasks, etc. Because the stainless-steel wire cloth is expensive, a paper or cardboard pattern is usually designed prior to the use of the metal.

ACKNOWLEDGMENT

The author gratefully acknowledges the valuable advice and technical assistance of Harry T. Owens and Gene Talmadge Sellers.

[1] Obtainable from Edward J. Darby & Son, 1517 Germantown Ave., Philadelphia 22.

Report of the

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS

PHOTOCATALYTIC PROPERTIES OF OXIDES[1]

SISTER MARIA CLARE MARKHAM
Saint Joseph College, West Hartford, Connecticut

SEVERAL studies of the photochemical properties of oxides have contributed to successful interpretation of the electronic structures of, and effects of ultraviolet light on semiconducting and phosphorescent materials, and have aided in solving many practical problems in applications of these oxides (*1–7*). This paper will deal principally with the oxides of zinc, antimony, and titanium, and the various types of photochemical change they undergo, including catalysis of the oxidation of organic compounds in ultraviolet light. Among the effects of ultraviolet light on these oxides are such phenomena as photoconductivity, phosphorescence or fluorescence, phototropy, and photolysis. A brief summary of the nature of these effects will provide the necessary background for interpretation of the initial effect of the ultraviolet light and of the manner in which external conditions influence the observable changes that follow.

Zinc oxide, titanium dioxide, and antimony trioxide are all white oxides with high reflecting power for visible light. Preparations of titanium dioxide are used for pigments and fillers in paints, paper, and occasionally in textiles. Figure 1 shows reflectance curves obtained in our laboratories for some of these oxides. If it were possible to "see" these oxides in ultraviolet light, they would all be "black." In the region from 4000 to 4500 Å., zinc oxide, for example, reflects nearly 100 per cent of the blue and violet light. Below 4000 Å. the reflectance drops off abruptly, and by 3700 Å. the absorption is complete. If zinc oxide is heated to a few hundred degrees centigrade it becomes bright yellow; the effect of the heat is evidently the production of disturbances in the lattice and the shift of the absorption curve into the blue and violet region of the spectrum. The oxide resumes its white color immediately on cooling.

Many of these oxides are also semiconductors; that is, they are poor conductors of electricity under ordinary conditions, but become better conductors when irradiated with ultraviolet light or when heated. For zinc oxide the region of absorption of light in the ultraviolet corresponds with the region of photoconductivity (*8*). It seems reasonable, therefore, to visualize the effect of the ultraviolet light as the exciting of an electron which

[1] Presented at the 280th Meeting of the NEACT, Mt. Holyoke College, April 23, 1955.

These photochemical studies have been supported in part by grants from Research Corporation and Sigma Xi.

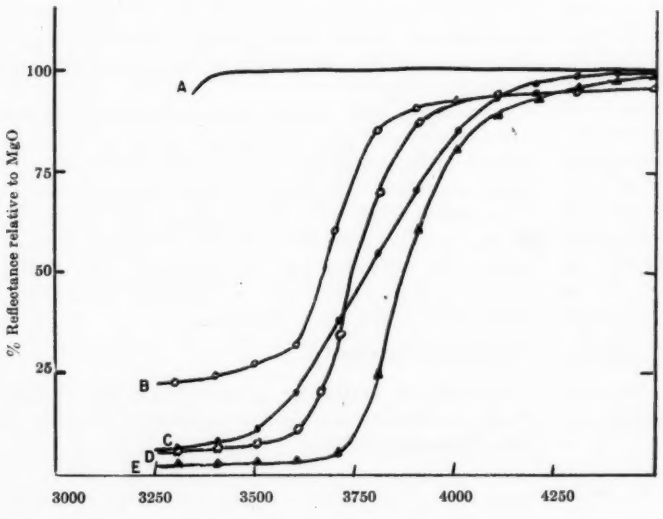


Figure 1

Reflectance curves for photochemically active oxides, relative to 100 per cent reflectance for MgO obtained with reflectance attachment to Beckman DU spectrometer. *A*, MgO; *B*, Sb_2O_3 (c. p.); *C*, TiO_2; *D*, Sb_2O_3 (pr.); *E*, ZnO.

can move from atom to atom within the crystal and produce an electric current when the crystal is placed in an external electric field. Titanium dioxide also shows photoconductivity (*9*).

In the absence of an electric field, irradiation with ultraviolet light produces random motion of the electrons and under certain conditions may lead to fluorescence or phosphorescence. Ordinary stoichiometric zinc oxide shows only weak fluorescence. If zinc oxide is prepared in such a way that it is a little short of oxygen, or contains excess interstitial zinc, it becomes brilliantly fluorescent, giving off blue-green light when irradiated with invisible ultraviolet light at 3650 Å. Apparently the excited electrons are trapped at defects in the crystal lattice, and eventually drop back to their normal positions, having lost part of the exciting energy, reradiating visible light. Such defects can be either slight deviations from stoichiometry or the presence of small amounts of foreign ions in the lattice.

The effect of the ultraviolet light is therefore supposed to be the transfer of an electron from an oxide ion to a neighboring metal ion. One can calculate the energy theoretically necessary to bring about such a transfer if one assumes an ionic lattice. The chief contributions to this energy would be: (1) the work necessary to remove a negative ion from its position in the lattice to infinity; (2) the work required to remove an electron from the negative ion in the gas phase (this energy should be equal and opposite in sign to the electron affinity of the element); (3) the work of removing an adjacent positive ion from its position in the lattice to infinity; (4) the energy gained by adding the electron to the positive ion in the gas phase (this energy should be equal and opposite in sign to the ionization potential of the element).

In this crude calculation only electrostatic effects are considered to make significant contributions to the energy of electron transfer. The work required to replace the neutralized atoms in the crystal between steps (2) and (3) and after step (4) is considered negligible. Several refinements are possible, but for an ionic crystal like sodium chloride even this rough estimate approximates the energy corresponding to the threshold of absorption in the ultraviolet. If one makes such a calculation for zinc oxide, however, the results are far off. One would estimate 13.5 electron volts, or about 300 kg.-cal.; whereas zinc oxide absorbs light at 3650 Å. (Figure 1), corresponding to 3.2 electron volts, or 75 kg.-cal. Similar discrepancies exist for calculations of the work of electron transfer in antimony and titanium oxides; these give a clear indication that the crystal structure is not simply ionic, and that there must be large polarization energies. In other words, the orbits of the outer electrons must be strongly distorted within the crystal structure, and the binding must be considered as something intermediate between ionic and covalent compounds.

In addition, the atoms on the crystal surface are subject to very uneven force fields, the electrons being attracted much more strongly by the atoms inside the crystal than toward the atmosphere on the side of the crystal boundary. Therefore, electron transfer can take place between ions on the surface with even less energy than that required inside the crystal. These more active surface units are believed to be responsible for the absorption "tail" in the reflectance curves in Figure 1, which would otherwise drop down more abruptly. The slope of the absorption curve is especially noticeable for titanium dioxide; Weyl and Forland (*2*) have described the magnitude of surface polarization effects in such oxides as titanium dioxide and silicon dioxide.

Both titanium dioxide and antimony trioxide, in certain crystal forms, exhibit the phenomenon of phototropy, that is, they change color on exposure to ultraviolet light, and return to their original white color a short time after the radiation is turned off. In both cases the rate and intensity of the color change are markedly increased by placing the crystals in contact with organic substances during the irradiation. When some forms of titanium dioxide are mixed with glycerol and exposed to ultraviolet light they turn blue-gray, and the original white color returns only very slowly after the light is turned off. Nonstoichiometric titanium dioxide with oxide ion deficiencies shows this same blue-gray color, and so do Ti^{+3} ions in certain solvents. Where there is an oxygen deficiency in the crystal, two of the adjacent titanium ions must have a charge of +3 instead of the normal +4. The "extra" electrons of these Ti^{+3} ions tend to crowd into the position of the missing oxygen, producing strongly distorted electron orbits which absorb visible light and are responsible for the observed blue-gray color. When stoichiometric titanium dioxide is irradiated in contact with organic substances capable of reacting with oxygen atoms, the transfer of the electron in the ultraviolet light leads to reduced titanium +3 ions and oxidized organic substances. The effect of the light is thus the decomposition of the oxide, a phenomenon known as photolysis. The action of light on photographic emulsions of silver halides causes a similar reaction to take place. The capture of one of the dissociation products by the formation of a stable chemical compound prevents the reversal of the electron transfer, and the color of the reduced oxide can only be bleached by slow reoxidation by the oxygen of the air.

Such photochemical reactions have been a serious problem for paint manufacturers who use large quantities of titania as a white pigment in paints. Paints containing certain types of titania darken on exposure to sunlight, and the carbon dioxide produced by the oxidation of the linseed oil in the paint causes cracking and flaking off or "chalking" (*3*). Textile chemists have also reported serious damage to rayon dulled with barium titanite; on exposure to moist air and sunlight, for example, when clothes are hung outdoors to dry, the material darkens and begins to disintegrate (*10*).

The author has worked with these oxides and studied their photochemical reactions for the past few years. One of the most unusual of these oxides is zinc oxide,

and one of its photochemical reactions seemed to be of particular interest as a possible conversion of solar energy to chemical energy: a sort of inorganic analogue of chlorophyll in photosynthesis.

When a suspension of zinc oxide in water is exposed to sunlight or ultraviolet light, in the presence of oxygen or air, hydrogen peroxide is produced. The oxide does not appear to be destroyed or permanently changed in the process, and seems to be acting as a photosensitizer for the reaction: $2H_2O + O_2 \rightarrow 2H_2O_2$, which involves a large increase in free energy. This would be an interesting way of storing solar energy in a chemical system, since zinc oxide absorbs all ultraviolet light which constitutes about four per cent of the total energy of sunlight.

One of the first things one discovers in working with zinc oxide is that both the rate of formation of hydrogen peroxide and the total quantity produced can be increased enormously by adding even small quantities of organic compounds. Some early workers who noted this effect suggested that the organic compounds were acting as stabilizers to prevent the decomposition of hydrogen peroxide, as acetanilide is added to the three per cent solution of hydrogen peroxide one buys in the drugstore. If this were so one could see how the final concentration of hydrogen peroxide might be increased, but not why the initial rate of formation should increase ten- or one hundred-fold. This evidence, together with the fact that one can trace the simultaneous

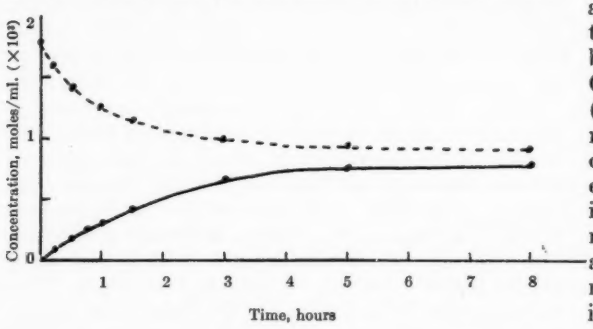


Figure 2

Equilibrium between rates of formation and decomposition of H_2O_2 on ZnO suspended in triply distilled water at 14°C., 3650 Å. Dotted curve represents rate of decomposition of H_2O_2 initially added to the water.

oxidation of the organic material, seems to indicate direct participation of the organic material in the initial chemical reaction which leads to peroxide formation. For instance, when phenol is added to a zinc oxide suspension, catechol is produced along with the hydrogen peroxide. Catechol is not the final oxidation product of phenol in this system; it reaches a small steady concentration and then begins to disappear. Catechol added to zinc oxide and water also promotes peroxide formation. Carbon dioxide seems to be the final product. During the formation of hydrogen peroxide in an irradiated suspension of zinc oxide in methanol solutions, carbon dioxide can be collected in a barium hydroxide trap, and formaldehyde can be detected in the early stage of the reaction. All of these organic compounds seem eventually to be oxidized to carbon dioxide.

If one traces the oxidation of phenol on zinc oxide one finds that the concentration of hydrogen peroxide increases up to a value from four to five times the concentration of the original phenol, and then gradually decreases. Tests at the maximum concentration of hydrogen peroxide show that all the phenol has been oxidized.

These results all seem to point to the conclusion that zinc oxide is a photocatalyst for the oxidation of organic materials. The zinc oxide can be filtered off, washed, and used over again with equally good results. The quantum yield of the oxidation is fairly high, from 0.5 to 1.0, which means that one molecule of hydrogen peroxide is produced and one molecule of oxygen is reduced to peroxide for every quantum of light absorbed. The quantum yield is a maximum in weak light intensity.

It looks as if the electron transferred by the light from an oxide ion to a zinc ion, momentarily forming Zn^{+1}, can be picked up by oxygen on the surface of the crystal, leading to the reduction of oxygen and the formation of peroxide ion. The zinc oxide crystal would then be left with a positive charge. If organic materials are present and can furnish electrons to the zinc oxide which then becomes neutral again, the overall effect is the oxidation of the organic substance and the reduction of oxygen from the air. We might symbolize the reactions as follows: $ZnO \rightarrow Zn^{+1}O$; $Zn^{+1} + O_2 \rightarrow Zn^{+2} + O_2^-$; $(ZnO)^+ + RH \rightarrow ZnO + RH^+$ (oxidized organic substance). If this interpretation represents the complete picture, zinc oxide is no longer of interest as a converter of solar energy to chemical energy, since the oxidation of these organic compounds is an exothermic process, but becomes important as a new type of photocatalyst. The zinc oxide and light are simply providing the activation energy to start the reaction as any thermal catalyst would do. Zinc oxide is well known as a thermal catalyst for the oxidation and dehydration of alcohols.

There are still some unexplained features. Even if spectroscopically pure zinc oxide and triply distilled water are used, one still finds small amounts of hydrogen peroxide in an aqueous suspension of zinc oxide in ultraviolet light. The rate of formation is very slow compared to a 0.001 *M* solution of phenol, for example, and the concentration reached is never very high, but stays at a value near 0.002 *M* apparently indefinitely (Figure 2). One would think that if organic material were necessary for the reaction, after a while whatever impurities might still be present in the zinc oxide or triply distilled water would be oxidized and the yield of peroxide would drop to zero. Instead one finds that the formation of hydrogen peroxide is reversible. Figure 2 shows what happens when hydrogen peroxide is added to the water initially. On zinc oxide in ultra-

violet light the hydrogen peroxide decreases and appears to be reaching the same steady-state concentration which one would obtain from the irradiation of the suspension in pure water. The function of the organic substance would then be the prevention of the reverse reaction by furnishing electrons to neutralize the positively charged crystals.

Certainly no peroxide is found in these suspensions in the absence of oxygen. The role of the water is not yet fully explained. In every case tried, the yield of hydrogen peroxide is greater in aqueous solutions than in pure organic liquids, although there are great differences in the magnitude of the optimum concentration of the organic compounds, varying from about 0.001 *M* for phenol to about 1.0 *M* for glycerol. Zinc oxide will catalyze other reactions in absence of oxygen; for example, the polymerization of vinyl monomers in dilute aqueous solution.

Further studies of these photocatalytic oxidations offer interesting possibilities for investigating the low-temperature oxidation of organic compounds. No attempts to find organic peroxides in these systems have been successful so far, but more work needs to be done before all the features can be explained satisfactorily.

The last section of this paper will be concerned with an oxide that seems to combine the possibility of photolysis characteristic of titanium dioxide with the photocatalytic properties of zinc oxide, the determining factor apparently being the crystal form. This oxide is antimony trioxide.

Early work by Goodeve (*1*) indicated that antimony trioxide acts in much the same way as titanium dioxide, absorbing light in the ultraviolet and turning dark. The brown color gradually fades in the dark. The rate and extent of darkening can be greatly increased by adding organic compounds, particularly glycerol. Goodeve prepared his photochemically active antimony trioxide by precipitating it from antimony trichloride with concentrated ammonia, and washing the sample free of chloride ions. He identified the crystal form as prismatic by X-ray diffraction. He also described an "inactive" form of antimony trioxide with a rhombic crystal pattern. This kind fails to darken in ultraviolet light.

We have prepared the prismatic antimony trioxide according to Goodeve's directions, and find that it does darken as he says, and that the addition of glycerol enhances the darkening. Presumably antimony is both oxidized and reduced in absence of organic matter: $5Sb_2O_3 \rightarrow 3Sb_2O_5 + 4Sb$. When organic matter is present Sb is produced, but oxidized organic substances probably result instead of Sb_2O_5. Little or no hydrogen peroxide is formed during the reaction.

However, commercial, c. p. antimony trioxide behaves like zinc oxide. It does not turn dark; hydrogen peroxide is found, and the optimum concentration of glycerol, for example, is about 1.0 *M*, just as it is for the oxidation of glycerol on zinc oxide. Addition of chloride ion or ammonium ion, which might possibly be impurities in the prismatic antimony trioxide owing to its method of preparation, has no effect on the c. p. substance. This seems to be a case where a substance can either undergo photolysis or act as a catalyst for oxidation, depending only on the crystal form. These two oxides had slightly different absorption curves as shown in Figure 1. It looks as if either water or oxygen (or both) can be held on the surface of one of these crystal forms in such a way that the transfer of the electron from the reduced metal to oxygen or water, leading to peroxide formation, can take place easily; the metal is reoxidized, hydrogen peroxide accumulates, and the organic material keeps on being oxidized. If there is some surface condition that prevents one of the essential reactants from being adsorbed in a strategic position, the metal is not reoxidized, the oxide darkens owing to reduction to the metal, and the organic material is oxidized only to a certain point; then the reaction comes to a stop.

This survey of the photochemical properties of oxides is by no means exhaustive. We have found ferrous ions oxidized to ferric in some cases. Formation of silver peroxide in suspensions of zinc oxide and titanium dioxide in silver nitrate solutions on irradiating with ultraviolet light (*11*), and bleaching of dyes (*12*) have also been reported. This brief discussion will give some idea of the many different types of photochemical reaction that can take place on metal oxides which absorb light in the near ultraviolet region, and the ways in which external and internal conditions can modify the initial effect of the ultraviolet light.

LITERATURE CITED

(1) Goodeve, C. F., and G. Cohn, *Trans. Faraday Soc.*, **36**, 433–40 (1940).
(2) Weyl, W. A., and T. Forland, *Ind. Eng. Chem.*, **42**, 257–64 (1950).
(3) Jacobsen, A. E., *ibid.*, **41**, 523–5 (1949).
(4) Markham, M. C., and K. J. Laidler, *J. Phys. Chem.*, **57**, 363–9 (1953).
(5) Ruben, T. R., J. G. Calvert, G. T. Rankin, and W. M. MacNevin, *J. Am. Chem. Soc.*, **75**, 2849–53 (1953); **76**, 2575–8 (1954).
(6) Markham, M. C., M. C. Hannan, and S. W. Evans, *ibid.*, **76**, 820–3 (1954).
(7) Vail, C. B., J. P. Holmquist, and L. White, *ibid.*, **76**, 624–5 (1954).
(8) Schwarz, E., *Proc. Phys. Soc.*, **A62**, 530 (1949).
(9) Earle, M. D., *Phys. Revs.*, **61**, 56 (1942).
(10) Pinte, J., and P. Rochas, *Bull. inst. textile France*, **31**, 9–17 (1952).
(11) Goetz, A., and E. Y. C. Inn, *Revs. Mod. Phys.*, **20**, 131 (1948).
(12) Goodeve, C. F., *Trans. Faraday Soc.*, **33**, 340 (1937).

To the Editor:

Some strange notions seem to be floating around the dream islands of the Pacific if those expressed by Judson L. Ihrig of the University of Hawaii in THIS JOURNAL (**32**, 217 (1955)) are representative of the whole. The idea that a heavy vapor will stay forever at the bottom of the air contained in a closed vessel is one which most teachers have little difficulty in dispelling, a few simple experiments on the diffusion of heavy and light gases usually sufficing. Professor Ihrig has evidently overlooked the fact that if the mothballs were indeed composed of *p*-dichlorobenzene, the evaporation of this material could proceed only until the partial pressure of its vapor reached the vapor pressure of the pure substance, which would be in the region of a millimeter of mercury at the ambient temperatures likely to prevail. The change in the oxygen content of the atmosphere enclosed in the trunk would be negligible. It is difficult to comment on why Professor Ihrig concludes that there would be "no back diffusion of oxygen from the air" because "there would be practically no convection currents." Diffusion takes place whether the convection is taking place or not. Convection could speed up the mass transfer of *p*-dichlorobenzene from the bottom of the trunk to the top, but in its absence diffusion would lead to a uniform composition of the atmosphere in the trunk in a very few hours at the most.

His doubts that "the action be a chemical one, since *p*-dichlorobenzene is not the sort of compound used as a rubber antioxidant" appear to be founded on equally shaky grounds. Perhaps those interested in rubber antioxidants know (I do not) whether *p*-dichlorobenzene is a rubber antioxidant, but can see reasons (I can) why it would not be suitable for use. Furthermore, if the erasers were likely to have swelled in direct contact with the substance on account of possible solvent action, they would equally well have swelled (albeit more slowly) in contact with the vapor.

I can visualize Professor Miller when next he wishes to put pencils having rubber erasers into a trunk, taking Judson L. Ihrig's advice regarding carbon dioxide! Three shillings' worth of pencils will be placed carefully at the bottom of the trunk (which will, of course, be fitted with numerous baffles to reduce back diffusion by hindering convection). Two holes will be bored in the trunk, one (near the bottom) for the introduction of carbon dioxide, the other (at the top) to let out the air displaced. He might make quite a profitable business from hiring out Kipp-type carbon dioxide generators, or supplying small chunks of solid carbon dioxide to avoid the necessity of boring holes in trunks! The alternative would be to fill the trunk with xenon; it is absolutely inert, nontoxic, and denser than carbon dioxide; furthermore, it would probably be just as ineffective.

JOHN D. JOHNSON

BEECHAM RESEARCH LABORATORIES LTD.
BETCHWORTH, ENGLAND

To the Editor:

All of the articles on foreign chemical literature in the March issue of THIS JOURNAL were very interesting and highly significant. In Table 10 of "A procedure for the identification of languages," by Benn E. Clouser and Herman Skolnik, errors occur regarding the Finnish equivalents of "reaction" and "study." "Vaikutus" means effect; reaction is "reaktio." "Lukeminen" means reading; study, in the sense of scientific investigation, is "tutkimus."

Ordinary bilingual dictionaries frequently give the common and literary, rather than technical, meanings of words. Where available, a technical dictionary should be used in making translations of technical articles. An excellent polyglot technical vocabulary, covering all fields of technology and the fields of science most important in technology, in Finnish as well as English, German, Swedish, and Russian, is "Tekniikan Sanasto" (two volumes, second edition, 1950), published by Kustannusosakeyhtiö Otava (Otava Publishing Corporation), Helsinki, Finland.

REINO HAKALA

FAIRFIELD UNIVERSITY
FAIRFIELD, CONNECTICUT

1 A	2 C	E	3 T	4 I	C	5 A	C	6 I	7 D
8 R	B	■	9 R	A	■	L	■	10 D	Y
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24 A	■	25 A	O	■	26 A	T	M	■	27 B
28 R	29 N	■	U	■	30 T	I	■	31 P	O
32 K	A	N	S	A	S	C	I	T	Y

Solution to Crossword Puzzle on Page 519

Recent Books

● NUCLEAR PHYSICS

Irving Kaplan, **Brookhaven National Laboratory. Addison-Wesley Publishing Company, Inc., Cambridge, Massachusetts, 1955. xi + 609 pp. Figs. and tables. 16 × 23.5 cm. $8.50.**

THE subject matter of this book is somewhat broader than the title may imply. The first 150 pages make up a section of seven chapters which deal largely with atomic physics and properties of radiation, and which give excellent background for consideration of the nucleus itself. The center 300 pages (10 chapters) cover topics found in most books on nuclear physics and include concepts of isotopy, radioactive decay, induced nuclear reactions, and nuclear structure. The last part (150 pages) consists of special topics of special applicability to the nuclear industry. These subjects which include neutron physics, fission, nuclear energy sources, and isotope separation give the book a flavor which should appeal to those not primarily interested in the rigors of nuclear theory. However, they will by no means be uninteresting to the physics student.

To cover as much ground as the author has set out to do in a single volume means of necessity that the treatment is not comprehensive. However, the author has done remarkably well in bringing together a large volume of information in a minimum number of pages. The author assumes that the reader has no knowledge of quantum mechanics and for those concepts which rest upon quantum mechanical formulation, descriptive passages are provided.

Among the other features of this book are copious references to the original literature, review articles, and other books. The references are well organized according to subject, and titles of all papers are listed. Each chapter is also followed by a generous list of problems which will be particularly helpful if the book is used as a text.

All in all, the author has done an excellent job in providing a book which should be intelligible to a wide range of readers. Although the author himself describes the treatment as elementary, it is not devoid of rigor and gives a good description of the present status of those phases of nuclear theory which are covered.

I. PERLMAN

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

● CHEMISORPTION

B. M. W. Trapnell, **Lecturer in Chemistry, Liverpool University. Academic Press, Inc., New York, 1955. vii + 265 pp. 87 figs. 69 tables. 14.5 × 22 cm. $6.80.**

THIS monograph is intended to present the subject of chemisorption in terms of theory and experiment in a manner which, while of greater interest to readers actively engaged in this field, is intelligible to the more general public. In this the author has succeeded; and it is remarkable that in such a concise work the author has not noticeably sacrificed clarity of exposition to brevity. The result has been achieved by the author's confining his discussion of experimental data either to more recent data or to only those older data obtained by the outstanding workers in this field. The reader, therefore, is spared a mere cataloguing of adsorption data and is presented with a highly selected set.

Following an introductory chapter there are nine chapters dealing with velocity of adsorption and desorption; adsorption isotherms, heat of adsorption; mechanisms of adsorption; mobility in adsorbed layers; catalytic specificity; and finally a chapter relating chemisorption to the mechanisms involved in catalysis. There is a good chapter on experimental methods, documented with reasonably up-to-date references, and a beginning graduate student would find this chapter a useful summary of prior work.

The chapters on the velocity of adsorption, in which adsorption is treated both by classical kinetic theory and by statistical methods, contain nothing which is new as far as the literature is concerned, but are logically developed, and the author clearly points out the assumptions and limitations of the various treatments.

The chapter on mechanisms of adsorption deals with the application of theories of metals, and discusses both the Mott-Jones and Pauling theories and the importance of *d*-orbital electrons in chemisorption processes. The chapter on catalytic specificity deals with geometric factors, following Ballandin's treatment, and with the influence of work function on catalytic activity.

The whole book is clearly illustrated, well printed, and attractive in format, but lacks an author index.

The weaknesses of the book, as far as this reviewer is concerned, lie in the presentation of the underlying thermodynamic theory relating to adsorption. By way of example, the opening sentence of Chapter I reads, "When two immiscible phases are brought into contact, it is nearly always found that the concentration of *one phase* (reviewer's italics) is greater at the interface than in the bulk. This tendency for accumulation to take place at a surface is called *adsorption*." What one hopes that the author intended to say is that at interfaces the concentrations of the various components of a heterogeneous system are generally different from those in the bulk phase. There is no attempt to make a good treatment of the adsorbed film as a surface phase, and the uncritical application of the Clapeyron-Clausius equation to so-called heats of adsorption, reaching back to the beginnings of adsorption, finds its place unquestioned in this book as in many others.

These shortcomings are small, however, and the reviewer can recommend the book not only as a convenient summary of the field for those professionally interested in adsorption, but as a useful work for teachers and for those seeking a general introduction to the subject of chemisorption.

ERIC HUTCHINSON

STANFORD UNIVERSITY
STANFORD, CALIFORNIA

● INORGANIC REACTIONS AND STRUCTURE

Edwin S. Gould, **Polytechnic Institute of Brooklyn. Henry Holt and Company, New York, 1955. viii + 470 pp. Figs. and tables. 16 × 24 cm. $6.50.**

THIS is a new type of textbook. The author intends it "to fill a gap in the training of college chemistry students." It falls between the descriptive textbook of the general chemistry course and the advanced reference text. It is not a reference book, but puts its emphasis upon the significance of internal structural relationships in the interpretation of properties and reactions. Some of the chapter headings will appear conventional (*e. g.*, Hydrogen and the Hydrides; Boron and Aluminum; Zinc,

Cadmium, and Mercury), but others will suggest the diversion of this book from conventional patterns: Ionic Crystals; Inorganic Nomenclature; Bond Energies, Electronegativities, and Covalent Bond Lengths; Chelates and Inorganic Stereoisomerism.

The first chapter includes as comprehensive and satisfactory a treatment of atomic structure and atomic energy levels as this reviewer has seen for students at this stage.

Advanced courses in inorganic chemistry have not yet become standardized in character and it would seem that one based upon this textbook could be very productive. Well planned exercises accompany each chapter.

NORRIS W. RAKESTRAW
SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA, CALIFORNIA

● MARVELS OF SCIENCE

Captain Burr W. Leyson, **E. P. Dutton & Co., Inc., New York, 1955. 189 pp. Illustrated. 14 × 21 cm. $3.50.**

HERE are the stories behind epoch-making industrial developments like the atomic battery and the transistor, the gas turbine and silicones. This engrossing book explains in simple, nontechnical language amazing new products and processes developed by American industrial science and tells of their practical applications in many different fields. It has been said that behind every man's invention is somebody's dream come true. Captain Leyson has revealed the dramatic stories of pioneer industrial scientists who have given us these priceless benefits we all enjoy. Readers of all ages will enjoy this new book because the author has a special talent for making difficult subjects clear and interesting.

GRETA OPPE
BALL HIGH SCHOOL
GALVESTON, TEXAS

● INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS

Galen W. Ewing, **Associate Professor of Chemistry, Union College. McGraw-Hill Book Co., Inc., New York, 1954. x + 434 pp. 298 figs. 31 tables. 16 × 23.5 cm. $6.50.**

THE author indicates in the preface that there have been few books which have attempted to present material on modern analytical techniques on a level suitable for upperclass undergraduates, or first-year graduate students, and that this book was written to fulfill the need for such a textbook. Therefore, this text presupposes only basic courses in quantitative analysis and general physics and does not require a knowledge of physical chemistry.

Part I of Professor Ewing's book consists of 21 chapters devoted to principles. In addition to those topics usually associated with the general term "instrumental method," the author includes chapters on Chromatography, Ion Exchange, Extraction Analysis, and The Determination of Water. Chapter 15 on The Analysis of Gases is very appropriate for an analytical course at the level designated by the author. Too often this topic is either slighted or completely ignored in the present-day analytical training of undergraduate and graduate students. The reviewer raises the question whether it would not be more profitable to deal more extensively and adequately with such topics as pH, potentiometric titrations, and colorimetry at this stage of the student's training than to delve into such topics as mass spectrometry, X-ray analysis, and Raman spectrometry. A chapter on Chemical Microscopy would be a valuable addition to future editions of this book.

The advantage of a single author of a textbook is manifest in the uniformity of writing style, the scope with which each topic is treated, and the constant degree of difficulty maintained throughout the book. The disadvantage of a single author, the lack of extensive practical experience in all phases of modern chemical analysis, is likewise detectable.

The text material is scientifically accurate and up to date with respect to nomenclature and recent developments in instrumentation and chemical analysis. Most of the chapters are followed by problems and questions related to the subject matter, which especially enhances the textbook value of this volume. A list of references also is given at the conclusion of each chapter.

Part II, entitled Laboratory Experiments, contains 33 exercises designed to acquaint the student with modern analytical techniques and methods. Laboratory exercises are not given for those methods requiring costly or very special instruments seldom available in collegiate instrumental analysis laboratories. Operating instructions for specific instruments are not given, inasmuch as these are always available from the instrument manufacturers and would be irrelevant in so many laboratories.

The format of this publication is attractive and the schematic illustrations are excellent. This book, in the reviewer's opinion, represents a significant and important step forward in the evolution of a satisfactory textbook for an intermediate course in analytical chemistry. Professor Ewing, in writing such an improved and satisfactory textbook, has performed a commendable service for teachers of instrumental analysis and for students taking these courses.

DAVID F. BOLTZ
WAYNE UNIVERSITY
DETROIT, MICHIGAN

● EXPERIMENTAL COOKERY FROM THE CHEMICAL AND PHYSICAL STANDPOINT

Belle Lowe, **Professor of Foods and Nutrition, Iowa State College. Fourth edition. John Wiley & Sons, Inc., New York, 1955. 573 pp. 78 figs. 43 tables. 15.5 × 23.5 cm. $7.50.**

"EXPERIMENTAL COOKERY" in its fourth edition is a comprehensive text, laboratory manual, and handbook for students specializing in foods. Its wealth of up-to-date information as well as over 1000 references cited should serve also as a quick reference book for food technologists in various areas.

The student is first given some basic background in colloid chemistry in which the phenomena of colloidal dispersions are related directly to foods. Thorough mastery of this first chapter is necessary in order for the reader to comprehend the ensuing discussions of specific foods which might otherwise appear to be vaguely treated at times.

Another excellent feature is the inclusion in this revision of a concise presentation of the factors in food acceptability, and the various methods utilized by food technologists in its evaluation. Certainly this is a timely subject inasmuch as success of a food product, whether prepared in a classroom, research laboratory, or commercial enterprise, will depend upon its palatability characteristics.

The text is presented in 14 chapters, 12 of which are devoted to the detailed discussion of specific foods or types of food product. Each is well organized and outlined with bold-type paragraph headings. Repetition is avoided by overlapping of chapters where one food product must be discussed from various aspects. For example, discussion on freezing of meat may be found under Frozen Foods and not in Meat and Poultry.

The subject information discussed in detail includes the following: crystal formation as in sugar cookery and frozen desserts; the freezing of various foods and food products; the plant acids, pigments, and related compounds; pectin and gelatin gels; animal proteins including meat and poultry, milk products, and egg products; emulsions; leavening agents; flour mixtures; and fat cookery. Foams are treated briefly and are incorporated into the various chapters on foods in which foam formation may be a problem—whether desirable as in whipped cream or egg foams, or undesirable as in jelly-making and vegetable cookery. Food processing and objective measuring devices are also treated briefly in the discussions of specific foods. Beverages, chemical additives, and food preservation methods have been given little or no attention. Most of the chapters are amply illustrated with

photographs, photomicrographs, and diagrams, and much of the research cited is supported with reproduced tables and graphs.

The laboratory manual consists of 68 experiments divided into the 12 chapter headings, with each group following its appropriate chapter. A sufficient amount of laboratory work is given to provide a year's course in experimental cookery. Beginning students may find the laboratory directions too brief, consequently a bit confusing because of the involved numbering system which really ties diverse aspects of an experiment into an integrated whole. The basic formulas are given both in common household measurements and in metric weights. Questions also may arise in the few instances where the author has seemingly been inconsistent in her laboratory directions, giving changes to be made in the basic formula in household measures rather than the usual gram weight. Both students and teachers should find the thought-provoking questions which are interspersed in the laboratory experiments helpful in explaining results of the experiments.

A compilation of such a multitude of literature from such a wide field into as complete and useful a work as is presented here is a Herculean task. Its usefulness, therefore, not only to colleges and universities but also to other areas of food technology, is extensive.

CORA MILLER

UNIVERSITY OF CALIFORNIA
LOS ANGELES, CALIFORNIA

● ADVANCES IN VIRUS RESEARCH. VOLUME II

Edited by *K. M. Smith,* Virus Research Unit, Molteno Institute, and *Max A. Lauffer,* Department of Biophysics, University of Pittsburgh. Academic Press, Inc., New York, 1954. x + 312 pp. Figs. and tables. 15.5 × 23.5 cm. $7.

AS INDICATED in the Preface to Volume I, the articles which appear in this book are designed to bring together in one place the widely scattered and rapidly expanding literature on animal, plant, bacterial, and insect viruses, and to permit investigators of different training and interests to interpret and integrate the results of virus research. In keeping with this plan, the editors have selected physicists, physical chemists, chemists, and biologists to prepare articles for this volume. The following is a list of titles and contributors:

F. O. Holmes, "Inheritance of resistance to viral diseases in plants"; F. C. Bawden, "Inhibitors and plant viruses"; P. von Magnus, "Incomplete forms of influenza virus"; W. W. Ackermann and T. Francis, Jr., "Characteristics of viral development in isolated tissues"; E. Pollard, "The action of ionizing radiation on viruses"; C. Knight, "The chemical constitution of viruses"; R. Williams, "Electron microscopy of viruses"; M. Lauffer and I. Bendet, "The hydration of viruses."

The high standards established in the first volume are also to be found in the second volume, with the result that this series serves as a valuable adjunct to the science of virology.

S. G. WILDMAN

UNIVERSITY OF CALIFORNIA
LOS ANGELES, CALIFORNIA

● QUALITATIVE ANALYSIS USING SEMIMICRO METHODS

Esmarch S. Gilreath, Associate Professor of Chemistry, Washington and Lee University. McGraw-Hill Book Co., Inc., New York, 1954. viii + 287 pp. 25 figs. 16 × 23.5 cm. $4.25.

THE title, "Qualitative Analysis" does not indicate the true nature of the book except for the laboratory section which is a minor portion of it. The first 175 pages are devoted to a rather rigorous treatment of molecular-structure equilibrium theory and oxidation and reduction, and was written to "bridge the gap" between a course in general chemistry and elementary physical chemistry. It might better be described as a book for a course in second-year college chemistry which uses as a laboratory assignment the conventional qualitative analysis scheme. The theoretical section is very well written with an adequate number of illustrative problems in each chapter along with sample calculations for each type of problem. The student is introduced to modern theories of bonding involving explanations based on atomic orbitals and bond energies, and the Brönsted-Lowry notation is used throughout. Oxidation-reduction theory is approached through a discussion of half-cells, and the Nernst equation is introduced. The term "molarity" which is usually used in discussing concentration has been discarded and replaced by "formality" and the symbol F used as an abbreviation. This new notation does not lead to confusion except in the application of the Nernst equation where F is also used to indicate a Faraday.

The laboratory section of the book contains prepared flow sheets based on the Fresenius system for each group of ions, and descriptive material containing equations for important reactions. The practice procedures consist of making a known solution for each group and carrying it through the scheme.

The appendix contains tables of information needed for the theoretical section plus an assignment schedule and a system for record keeping.

In schools where qualitative analysis is taught as a separate course in the second year and not combined with general chemistry, this book fulfills the purpose more than adequately.

JAMES F. CORWIN

ANTIOCH COLLEGE
YELLOW SPRINGS, OHIO

● ACETYLENE COMPOUNDS IN ORGANIC SYNTHESIS

R. A. Raphael, Professor of Organic Chemistry, The Queen's University of Belfast. Academic Press, Inc., New York, 1955. xii + 219 pp. 14.5 × 22.5 cm. $6.20.

THIS is a timely book on a subject which is of interest to all organic chemists. Acetylene and its compounds comprise a very useful tool in organic synthesis. With a high order of reactivity, remarkable stability, and wide variety of reactions, they provide the synthetic organic chemist with a powerful tool in his work, whether it be the synthesis of a particular geometrical isomer or of a complex natural product.

Since an increasing number of acetylenic compounds have become commercially available, there has been an expanding search for new applications. This has led to new reactions, new products, and revised techniques. In turn, this has added greatly to the literature as well as to the confusion confronting the researcher who is inexperienced in acetylene chemistry.

The author has used his wide practical knowledge in this field as a guide in the preparation of a much needed review. His objective has been to span, in one volume, the broad literature of acetylene chemistry, and to offer practical advice on the choice of available techniques. In this goal he has succeeded very well.

The text has been divided into six sections covering the whole field of acetylene chemistry, with the exception of technology. The basic reactions of acetylene chemistry are described in general in the first section and applied to specific syntheses in the body of the text. For convenience they have been divided into aliphatic compounds, conjugated systems, carbocyclic compounds, and heterocyclic compounds. A final chapter illustrates a number of the more general reactions by detailed directions.

As is necessary in the review of such a broad field, there is not the wealth of fine detail found in more specialized texts. Each section, however, is concluded by a list of selected references which lead the researcher at once to the most relevant literature. Throughout the book the author has pointed out areas which have been little explored and offers them as fruitful fields for research.

EUGENE G. TEACH

U. S. DEPARTMENT OF AGRICULTURE
ALBANY, CALIFORNIA

● BIOCHEMICAL INVESTIGATIONS IN DIAGNOSIS AND TREATMENT

John D. N. Nabarro, Assistant Physician, Middlesex Hospital, London. Little, Brown and Company, Boston, 1955. ix + 299 pp. 5 figs. 8 tables. 14.5 × 22 cm. $6.

"Biochemical Investigations" is a book which should prove useful to the doctor in his practice as well as to the clinical chemist who serves him. The author says, "If used with discrimination they [biochemical tests] may help to solve problems of differential diagnosis, and in many cases they are essential for proper control of treatment." Judicious selection of procedures is of utmost importance for the patient, and indiscriminate use of biochemical procedures has always accounted for much unnecessary and unproductive clinical laboratory effort. It is unfortunate that the chemist who is unequipped to come to grips with medical problems must so frequently guide the doctor by recommending what tests ought to be done and in interpreting the results of these tests for the physician. It is in just these areas that the book will prove helpful. The physician-author has written the book from the bedside viewpoint rather than from that of the laboratory, and consequently has produced something different from most currently available texts in the field. He has taken up matters of disturbance in water balance, acid-base and electrolyte equilibrium, mineral metabolism, carbohydrate, protein, and fat metabolism, diseases of the gastrointestinal tract, liver, kidneys, and endocrine glands, and some consideration of vitamin deficiencies and common poisons. Each section contains a brief review of the fundamental physiology involved and a discussion of the common tests and their significance in diagnosis. For the sake of brevity, technical laboratory details are generally omitted and reference is made to original papers or other texts for such information. The bibliography, it seems to this reviewer, is a little brief and might have been expanded to include more alternative procedures, thus adding breadth to the treatment. Despite this fact the book is practical for its purposes and should find wide use. Not the least valuable feature is that of the useful tables on the normal values for concentration of materials in the different body fluids.

ELIOT F. BEACH

Metropolitan Life Insurance Company
New York, N. Y.

● THE PROTEINS: CHEMISTRY, BIOLOGICAL ACTIVITY, AND METHODS. VOLUME II, PART B

Edited by _Hans Neurath_, Department of Biochemistry, University of Washington, and _Kenneth Bailey_, Department of Biochemistry, University of Cambridge, England. Academic Press, Inc., New York, 1954. ix + 1418 pp. 90 figs. 6 plates. Tables. 16 × 23.5 cm. $16.50.

This volume completes the four-volume series embracing an exhaustive review and discussion of our present knowledge of the proteins. Considered together these four volumes will be referred to for many years, not only for all phases of the chemistry of these important macromolecules, but also for their biological properties and biological activities.

In keeping with the pattern of the earlier volumes, the authors of the chapters in this book present their material in great detail so that the reader is provided with a broad background of theoretical considerations as well as applications.

Six chapters (Chapters 21 to 26) make up this Part B as follows. "Interstitial proteins. The proteins of blood plasma and lymph," by Walter L. Hughes; "The proteins of immune reactions," by William C. Boyd; "Structure proteins, I," by J. C. Kendrees; "Structure proteins, II: Muscle," by Kenneth Bailey; "Proteolytic enzymes," by Michael Green and Hans Neurath; "Peptide and protein synthesis. Protein turnover," by H. Tarver. An author and subject index to Parts A and B of Volume II is appended.

The reader will be impressed with the contributions that the use of purely physical methods have made to the elucidation of protein structure. Indeed, almost all current concepts of the configuration of structure proteins such as the keratins, collagens, and muscle proteins rest on X-ray diffraction patterns, spectroscopy, electron micrographs, and other measurements more commonly employed by the physicist than the chemist.

The observation made in a review of an earlier volume in this series may now be repeated as applying to the complete four-volume work: It is not written for the casual reader but for the advanced student and research worker in the field of protein chemistry. To such it can hardly fail to be a continual source of information and stimulation.

F. A. CAJORI

University of Colorado
Denver, Colorado

● SEMIMICRO QUALITATIVE ANALYSIS

F. J. Welcher, Professor of Chemistry, Indiana University, and _R. B. Hahn_, Associate Professor of Chemistry, Wayne University. D. Van Nostrand Co., Inc., New York, 1955. x + 497 pp. 40 figs. 58 tables. 15.5 × 23.5 cm. College, $6.50. Reference, $8.

This book provides much more factual information than the typical qualitative book. In fact, it is so far removed from the usual qualitative manual that it probably rates the name reference work. In line with this approach there is much more detailed coverage of properties and reactions, and more space devoted to reasons for deviations from expected behavior of a solution.

The sections (648) are numbered and thus allow ready pinpoint cross reference. There are many questions and problems provided throughout the book. Perhaps the most unusual feature of the book is the inclusion at the center of the book of a splendid collection of tables. In addition to the usual tables of ionization constants, solubility products, etc., there are two fine ones: Properties of Inorganic Compounds, and Properties of the Metals and Ions. The book gives the student every opportunity to avoid the pitfall of "cook-book chemistry" lab work. The mass of information here assembled may prove to be a handicap to the poor student because he fears that there is so much he cannot get any.

The chief problem appears to be just where to fit a course using this book as a text. It is too solid to waste on a haphazard part-semester qualitative course. There is not enough descriptive matter for a full semester of general chemistry. It does seem ideal for a course in qualitative analysis, a use for which it was carefully written.

HARRY H. BATEY, JR.

State College of Washington
Pullman, Washington

● ISOTOPIC GAS ANALYSIS FOR BIOCHEMISTS

R. F. Glascock, Head of Isotope Section, National Institute for Research and Dairying, University of Reading. Academic Press, Inc., New York, 1954. vi + 247 pp. 74 figs. 8 tables. $5.80.

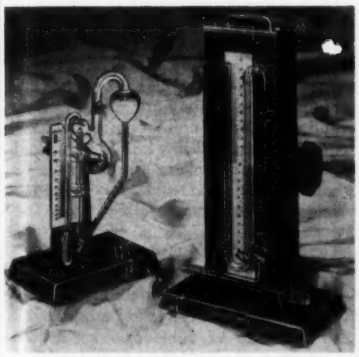
Contains enough pointers on high-vacuum apparatus, handling small gas volumes, and radioactive counting procedures to make the book valuable to workers in many fields. The particular subjects dealt with, taken largely from chapter headings, include: radioactive assay methods; gas phase analysis of carbon-14; determination of deuterium and of tritium; preparation of labeled compounds and their combustion. Copious use of extracts from the original literature go far to reduce emphasis upon typically British methods and procedures.

Out of the Editor's Basket

Vacuum Gauges

A Bennert type Manometer, for the determination of absolute pressures in the range of 0 to 240 mm., is now being manufactured by the Kontes Glass Company. Zero adjustment of the moveable scale is provided through a rack and pinion gear assembly enclosed within the instrument. A control knob mounted on the side of the aluminum housing permits an operator to manipulate the sliding scale with ease and accuracy, according to the manufacturer. Glass component parts can be obtained separately and installed by the user in the event of breakage.

The improved Lippincott McLeod Gauge, manufactured by Kontes, zeros automatically and incorporates an alignment stop bracket. The automatic zero is a mercury overflow device which regulates the height of the reference or control capillary leg to the zero point on the scale. Excess mercury is caught in a built-in trap. Alignment stop bracket arms prevent rotation of the glass portion of the gauge beyond the reading and evacuating positions. The gauge is provided in four ranges: 0–1 mm., 0–5 mm., 0–10 mm., and 0–15 mm. It may be used as a bench instrument, mounted on a framework or inserted in an all glass system.



Complete details on both instruments may be had by writing Kontes Glass Company, Vineland, New Jersey.

Ion-Exchange Demonstration Kit

A new research model demineralizer or ion-exchange kit is announced this month by the Barnstead Still & Sterilizer Company. The new Model RE-1 Research Demineralizer has been developed to provide a laboratory with all of the basic material and reference data needed to explore the properties of twelve of the newest cation and anion resins in both highly basic and weakly basic types.

The complete unit consists of two transparent Lucite ion-exchange columns, twelve jars of resins of assorted types, five cation and seven anion, and a manual of more than 100 pages of technical data on the resins. Instructions for operating as a mixed-bed or a two-bed ion-exchanger are included and additional units can be connected in series for multiple-bed experiments.

This new ion-exchange kit can be used for research or as a demonstration unit, and should prove an effective teaching or instruction aid. It permits experiments on a small scale so that results are quickly available. More complete information may be had by writing to Barnstead Still & Sterilizer Co., #108 Lanesville Terrace, Forest Hills, Boston 31, Massachusetts.

Safety Device for Inserting Glass Tubes in Stoppers, Corks and Bulbs

A new safety device for inserting glass tubes in rubber stoppers, rubber tubing and bulbs, has been announced by Central Scientific Company, Chicago. Called the Cenco "Tube-On" Safety Tube Inserter, the device is said to virtually eliminate the danger of lacerated fingers or hands which too often is the result of breaking a glass tube while inserting it.

In addition to minimizing tube breakage and increasing laboratory safety, the "Tube-On" makes sleeving jobs easier and faster. Only a few seconds are required for even an untrained person to perform the operation.

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"Since really qualified translators are rather expensive, anyone who needs to refer to Russian periodicals with reasonable frequency would find it well worth his while to study Russian for himself. The language, and especially its technical form, is not particularly difficult to learn. It is reasonable, direct and phonetic . . . . . .

"Since every chemist has to be reasonably intelligent, he needs only persistence and Chemical Russian, Self-Taught to learn this scientifically important language. Dr. Perry says that it would require approximately a year, with an hour's study each day, to learn to read Russian fairly well. All progressive scientists have considerable experience in studying by themselves, however, and should absorb a great deal more knowledge in a given period of time than the average student. I therefore feel that anyone devoting half an hour each evening to Russian instead of the usually recommended cultural literature, could master technical Russian adequately in six months.

"Any chemist at all interested in studying Russian should be much encouraged on reading Dr. Perry's chapter entitled Suggestions for Study Methods. Here the approach to study of Russian is analyzed logically and clearly. And he will certainly want to take advantage of all the useful material packed so solidly into the thoughtfully organized chapters on Vocabulary Problems, Inorganic Chemical Nomenclature, Organic Chemical Nomenclature, and Russian Grammar, as well as the Glossary of Technical Terms which contains almost 2,000 words. In fact, this book would be a good investment even to those chemists who want to learn only enough Russian to read the titles of technical articles."

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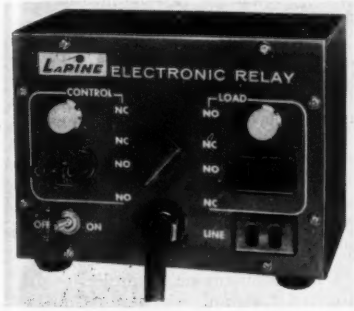

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▲ The Rimenco Laboratory clamp which operates on an entirely new principle has just been introduced in this country by R. I. Mendels, Inc., 41 East 42nd St., New York 17, N. Y. The Rimenco clamp uses a band of spring steel as the clamping device. This band allows the clamping pressure to be distributed around the entire circumference of the glassware instead of concentrating it in one spot as with ordinary clamps. The glassware is held tightly but flexibly. Consequently, clamping breakage is virtually eliminated.

Prices and complete information may be obtained from R. I. Mendels, Inc.

▲ A new "Standard Taper" Joint Clamp, completely eliminating the need for hooks and springs, has just been introduced by The Emil Greiner Co., M. 20-26 Moore St., New York 13, N. Y. Developed especially for the Emil Greiner Co. by the Manostat Corp., this small, compact one-piece unit, of corrosion proof aluminum construction, is designed to fit all makes of standard taper TS Joints . . . both Corning and Kimble. The clamp provides a positive lock . . . has a simple screw adjustment to control clamping pressure. These clamps have the additional practical advantage of being easily attached to apparatus already set in place.

▲ A new instrument, the Gas Density Balance, has been added to the line of advanced instruments manufactured by Arnold O. Beckman, Inc., 1020 Mission St., South Pasadena, California. The instrument measures the density of a sample gas by a unique null balance principle. A small dumbbell is supported on a horizontal quartz fiber. One ball of the dumbbell is punctured so that it will not experience buoyancy effects. The other ball tends to rise or dip as the density of the gas increases or decreases. Thus, the dumbbell creates a rotational force about the quartz fiber as it responds

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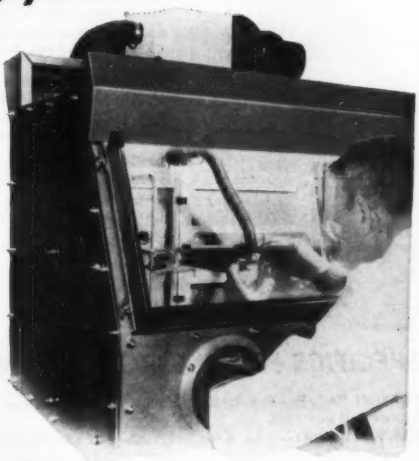

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▲ Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Illinois, has redesigned the "Temp-Trol," a portable constant temperature circulating system used for accurate temperature control of refractometers, spectroscopes, viscosimeters, colorimeters, jacketed conductivity cells, spectrophotometers, saccharimeters and other instruments.

▲ Rubber stoppers as well as corks up to 4″ diameter are bored smoothly with Eberbach's versatile new Stopper & Cork Borer. Whether wall - or table-mounted, it may be used interchangeably in either a horizontal or vertical position, for the machine frame is secured in the slotted base-plate by two lock screws. Bulletin 600, Eberbach Corp., Ann Arbor, Michigan.

▲ A new semi-automatic projection balance, the Unigram, which reads directly to 200 grams in steps of 0.1 milligram is being manufactured by Voland and Sons, Inc., New Rochelle, New York. This versatile weighing instrument weighs in seconds, requires no external weights, gives unequalled reproducibility, and resists vibration. With all this its use, readability, setting up, and maintenance is a model of simplicity.

▲ Precision Scientific Company has redesigned the Ful-Kontrol Heater, an electric laboratory heater with a built-in auto-transformer, providing stepless control of power input from 0 to 750 watts.

▲ An Air-Well Bath for the detection of free and corrosive sulphur compounds is now available from the Modern Laboratory Equipment Co., Inc., 1809 First Ave., New York 28, New York, makers of scientific laboratory equipment.

▲ Grieve-Hendry Co., Inc., 1401 W. Carroll Ave., Chicago 7, Illinois, announces a new addition to their standard line of low-cost ovens, called Model PL-2A, for drying operations such as plastic granules, parts after cleaning and loose materials that require dehydration.

▲ Master Slave Manipulators, devices for handling radioactive materials in nuclear research, heretofore made-to-order, are now being produced in quantity for the first time by AMF Atomics Inc., subsidiary of American Machine & Foundry Co.,

261 Madison Ave., New York 16, N. Y.

▲ A new durable laboratory balance with features that simplify and speed up weighing operations has been announced by the Torsion Balance Co., Clifton, New Jersey. The features of the new Model LA-3 include torsion bands made of Elgiloy, a stronger, corrosion-resistant alloy, which results in longer, trouble-free life for the balance.

▲ Hamner Electronics Co., Inc., of Princeton, New Jersey, announces its N-401 High Voltage Power Supply, which provides the high degree of stability previously available only with batteries. The stability is limited only by the voltage reference tubes, which are the new ultrastable 85A2 types operated under constant current.

▲ Brooks Sho-Rate "50" Purge Meter advanced concept in metering small flows of liquids or gases. A dependable and efficient instrument for everyday plant use . . . versatile and economical. Complete details, dimensions drawings, and capacity charts included in Brooks Rotameter Co. Bulletin No. 145, Lansdale, Pennsylvania.

▲ Explosion proof, powered by air, stirring units for solvents, lacquers, paints, oils and chemicals available from Arrow Engineering Co., Inc., 200 Central Ave., Hillside, New Jersey.

NEW CHEMICALS

● Calciura Carbonate Primary Standard is the seventh primary standard to be added to the Mallinckrodt Chemical Works' line of analytical reagents.

This standard was developed to serve the analytical requirements of flame photometry and versene titrations. It provides an ideal calcium standard, especially for these uses.

Detailed information is available on request from Mallinckrodt Chemical Works, St. Louis 7, Missouri.

● General Chemical Division, Allied Chemical & Dye Corporation, has added a full range of radiochemicals to its line of Baker & Adamson laboratory reagents.

Under its Baker & Adamson label, General Chemical will make available organic and inorganic radiochemicals, including Carbon-14 labeled compounds, and deuterated compounds. These products are supplied in a more readily usable form than those available from the Atomic Energy Commission.

In a special catalogue describing these new radioisotope reagents, the company lists the chemicals and gives details on obtaining necessary A.E.C. authorization for purchase of radiochemicals. The catalogue also contains background information on what radiochemicals are and how they are being used in industrial research as an aid to those who want to know more about this new field.

NEW FILMS AVAILABLE

✧ The first edition of the Scientific Apparatus Makers Association film directory is now available. It lists all free movie strip films available to interested viewers through SAMA members.

The entire project, sponsored by the laboratory apparatus and optical sections' public information committee, is in response to many requests for this type of service from science educators, industry, government agencies, churches and civic groups.

The attractive two-color, easy to file folder tells of the availability of 14 motion pictures on subjects ranging from optical instruments to basic electronics. Film information is outlined for each picture according to title, film size, color or b. w., running time, description of picture and source.

A helpful strip film teaching series dealing with industrial instrumentation and process control equipment is also listed for free loan or purchase.

As noted in the directory, all films should be ordered directly from the SAMA members sponsoring them. The Association public information committee acts as a clearing house of information only in bringing the titles to your attention.

Single copies of the SAMA motion picture film directory may be obtained free from: Public Information Committee, Scientific Apparatus Makers Association, 20 No. Wacker Dr., Chicago 6, Illinois.

✧ A new edition of their motion picture catalogue which gives complete information on all films currently being distributed by United States Steel Corporation, is now available. Sixteen subjects are listed, all in sound, the majority in color. All are available in 16 mm., a few in 35 mm., without any rental charge.

Copies of the catalogue may be had by writing Motion Picture and Visual Aid Section, United States Steel Corp., 525 William Penn Place, Pittsburgh 30, Pa.

NEW LITERATURE

● A new 8-page booklet titled *Questions and Answers on Electron Microscopes* is available gratis from the Research and Control Instruments Division, North American Philips Company, Inc., 750 South Fulton Ave., Mount Vernon, New York. The booklet explains such things as shadow casting, use of the same instrument for electron diffraction, resolution, visual and camera work, specimen preparation, negative and positive replicas, as well as electron and lens theory.

● Bulletin L-8 on *Chemical Porcelain Laboratory Sinks* has just been released by The U. S. Stoneware Company.

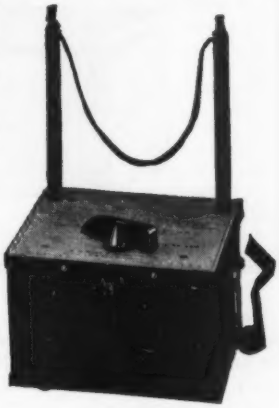
This 20-page 3-color bulletin, fully illustrates U. S. Stoneware's complete line of Chemical Porcelain Sinks. This new bulletin describes fully how U. S. Lab Sinks are made as well as showing dimensional drawings and charts for U. S. Sinks, Outlets, Drains and Traps.

Readers can obtain a copy of this new bulletin, without charge, by writing: Mr. S. A. Lewis, The U. S. Stoneware Co., 60 E. 42nd St., New York, N. Y.

Obtain NEAT, QUICK CUTS
with the Welch
HOT-WIRE GLASS-TUBING CUTTER

Glass tubing bottles, or jars up to 3 inches in diameter can be cut neatly and quickly with this cutter. Soft glass, Pyrex-brand glass, or other hard-glass tubes can be cut with equal ease. The article is first encircled with a scratch made by a cutter wheel conveniently mounted on the side of the transformer, the scratch is heated by contact with the hot wire, and then cooled quickly by applying water or by blowing on it. No other equipment is required.

The cutting wire is supported on two insulated posts and is heated by current from a 12-volt transformer serving as the base. No. 24 (B & S gauge) nichrome wire is used and is easily replaced. Three extra wires are included. By means of an adjustment on the transformer, the current can be controlled to give the optimum heat for whatever type of glass may be used. An instruction plate is mounted near this control. The unit operates on 115 volts, 50 or 60 cycle A.C. Over-all dimensions are 6 x 4½ x 9 inches high.



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HOT PLATE

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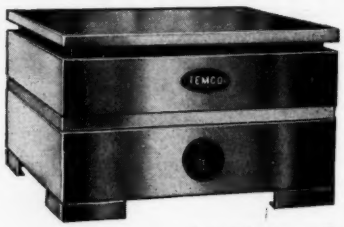

Type 2600 . . . 9″ square

Here's another new model in the wide line of highly dependable TEMCO hot plates. It is designed especially to stand *hard use* for prolonged periods. Built with extra strength to support heavy loads . . . smooth cast iron top plate ideal for all types of work. Nickel-chromium alloy heating element embedded in a refractory plate of high thermal conductivity. Well ventilated for efficient, trouble-free operation. 4-heat control: L-400°; LM-535°; M-710°; H-930° F. (without load). Two models for 115V and 230V a-c operation. 9″ square, 6″ high. $35. Write for data and name of nearest dealer.

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Available in sizes 1″ O.D. to 1⅝″ O.D. Lengths to 36 in.—plain and constricted end.

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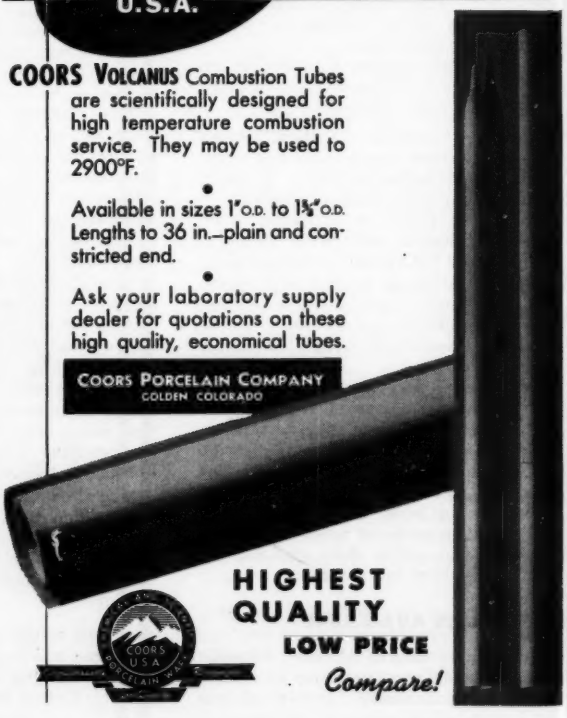

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● A new 48-page, two-color catalogue just released by the Nuclear Instrument and Chemical Corporation, 229 W. Erie St., Chicago 10, Illinois, describes a complete line of radiation measuring equipment for medical, industrial, and research applications. A radio chemical price list containing 144 different Carbon-14 labeled radioactive compounds is also included. Copies will be sent on request.

● A new type of polyethylene which has greater heat resistance, greater structural stiffness, and better appearance than the regular product, is the subject of an illustrated booklet titled *Super Dylan Polyethlene, C-5-216*, prepared and released by the Chemical Division of Koppers Company, Inc., 1301 Koppers Building, Pittsburgh 19, Pennsylvania.

● Included in the new 25-page *Pfanstiehl Specification and Price Catalogue* are rare sugars, sugar derivatives, amino acids, and other biological chemicals, most of which are now available in bulk as well as laboratory quantities. Among the items of particular interest covered by the catalogue are levulose, galactose, bilirubin, salicin, as well as calcium and sodium glucoheptonate. A copy of the catalogue may be obtained by writing Pfanstiehl Laboratories, Inc., 104 Lake View, Waukegan, Illinois.

● A new 52-page catalogue of its complete line of high vacuum pumps, featuring an engineering section containing formulae and data of practical value to all vacuum engineers, is available from Kinney Manufacturing Division, the New York Air Brake Co., 3640 Washington St., Boston 30, Massachusetts. Designated *Catalogue No. 425*, attractively printed in two colors, profusely illustrated, and containing many cutaway drawings, diagrams, graphs, performance curves, installation pictures, tabulations of data, conversion tables, charts and formulae, this publication is actually a comprehensive vacuum engineering reference book.

● National Aluminate Corporation is currently offering literature on catalysis with ion exchange resins . . . . describing theory conditioning procedures, and catalysis techniques. A table of the various types of reactions which have been catalyzed is also included. Address National Aluminate Corp., Ion Exchange Division, 6216 West 66th Place, Chicago 38, Illinois.

● The complete line of Fischer & Porter filled thermal systems for indicating, recording, controlling, transmitting, compensating, and programming temperatures from −400 to +1000 degrees Fahrenheit are illustrated and described in a catalogue just published by Fischer & Porter Co., Hatboro 35, Pennsylvania.

● *Bulletin #161*, Gardner Automatic Photometric Unit gives up-to-date information on the measurement of surface qualities. Used with a variety of exposure heads it can make rapid and automatic measurement of gloss, haze transmittance, goniophotometry, reflectance, and color. Write Gardner Laboratory, Inc., Bethesda 14, Maryland.

● *Glass Fiber Filter Discs*, a four-page, two-color bulletin covering a complete range of septa for every commercial use, has just been issued by Freidrich and Dimmock, Inc., Millville, New Jersey.

● A new four-page folder on the "Vidigage" Utrasonic resonance thickness gage has been released by Branson Instruments, Inc. Operating principles, typical applications, and features are described in the folder. The folder and other descriptive material may be obtained by writing to Branson Instruments, Inc., 430 Fairfield Ave., Stamford, Connecticut.

● High Pressure Equipment Co., Inc., Erie, Pa., has released *Catalogue No. 2055* which fully describes the rapidly expanding line of high pressure valves, adaptors, reactors, autoclaves, thermocouplings, gauges, fittings, and tubing manufactured by this relatively new company.

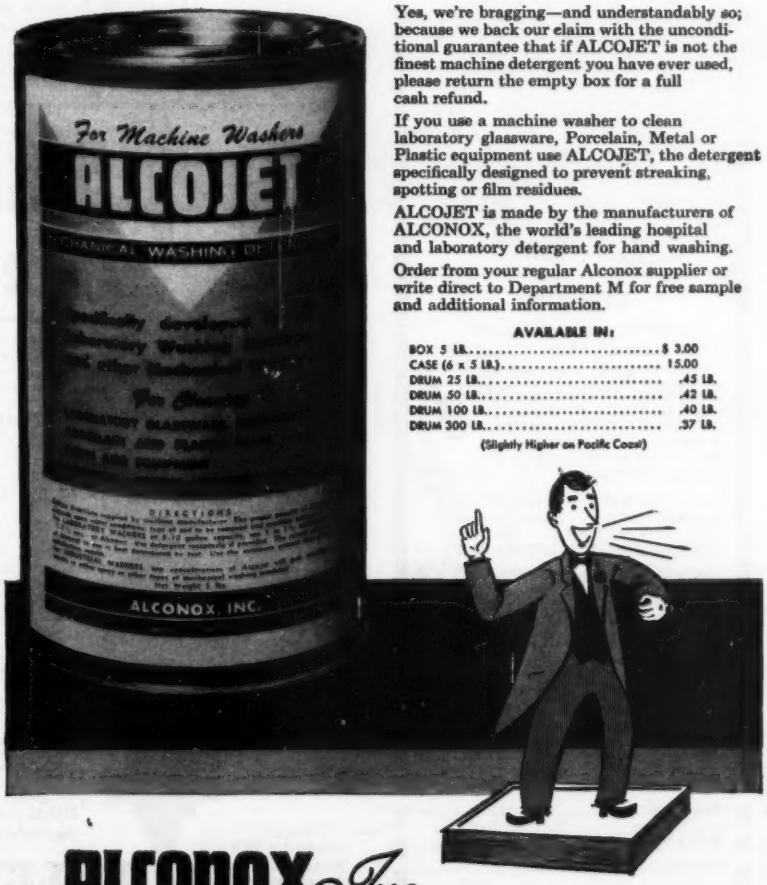
● Suggestions for the preparation and effective use of color slide sequences in business and education presentations are embodied in an Eastman Kodak pamphlet extensively revised and now ready for distribution. Copies of this 8-page *Notes on Color Slide Sequences as Aids in Business and Education*, punched to fit the Kodak Photographic Notebook, are available without charge from the Sales Service Division, Eastman Kodak Co., Rochester 4, New York.

● The proximity meter, a precision electronic instrument that measures without touching the specimen, is described in a new 28-page booklet offered free by the manufacturer, Fielden Instrument Division of Robertshaw-Fulton Controls Co., 2920 N. Fourth St., Philadelphia 33, Pennsylvania.

Only **ALCOJET**

gives you the Big Difference

in lab machine detergents



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ALCOJET is made by the manufacturers of ALCONOX, the world's leading hospital and laboratory detergent for hand washing.

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CASE (6 x 5 LB.)	15.00
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DRUM 50 LB.	.42 LB.
DRUM 100 LB.	.40 LB.
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for your most exacting LABORATORY NEEDS

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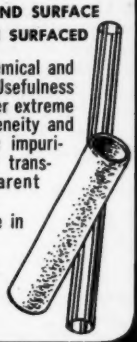

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BULLETIN 22 for specification and prices.

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CRUCIBLES: Permit production of compounds of real purity. No material absorption, non-catalytic, non-porous. Can be wire-wound for electrical heating. Glazed and unglazed. Immune to extreme chemical, thermal, electrical conditions. **DISHES:** For concentrations, evaporation, crystallizing acid solutions. All sizes and types. **TRAYS:** Many sizes available from stock. Special sizes can be supplied promptly. **BULLETIN 21** for specification and prices.

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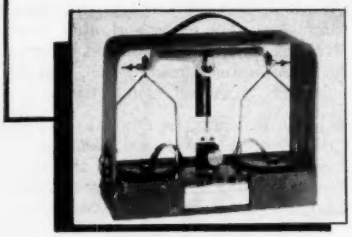

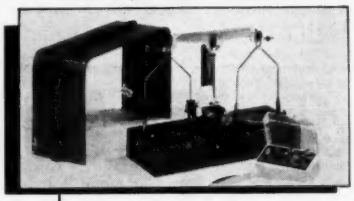

CAPACITY: 100 grams in each pan.

SENSITIVITY: 1 milligram with full load.

BEAM: Graduated 0 to 100 Mgs. by 1 Mg. increments. Sliding rider for beam runs in track at back of beam and cannot be dislodged.

PANS: Stainless Steel, 2½" diameter.

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WEIGHTS: Complete set from 100 mgs. to 50 grams, with forceps.

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The **PERMA-DEMON** is the only Water Demineralizer of its size that does not require Cartridge Replacement by the Manufacturer. It performs with the same economy as any larger Cartridge Type Demineralizer. Available now.

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mineral content parts per million (as $CaCO_3$)	output-Gallons per refill (1 pound of material)	cost per gallon per lb. of material—in cents
50	210	1.2
100	102.5	2.4
150	69	3.6

based on material costing $3.25 per lb. and credit of 75¢ per lb. for exhausted material returned to Enley Products Inc. NET COST OF MATERIAL $2.50 per lb.

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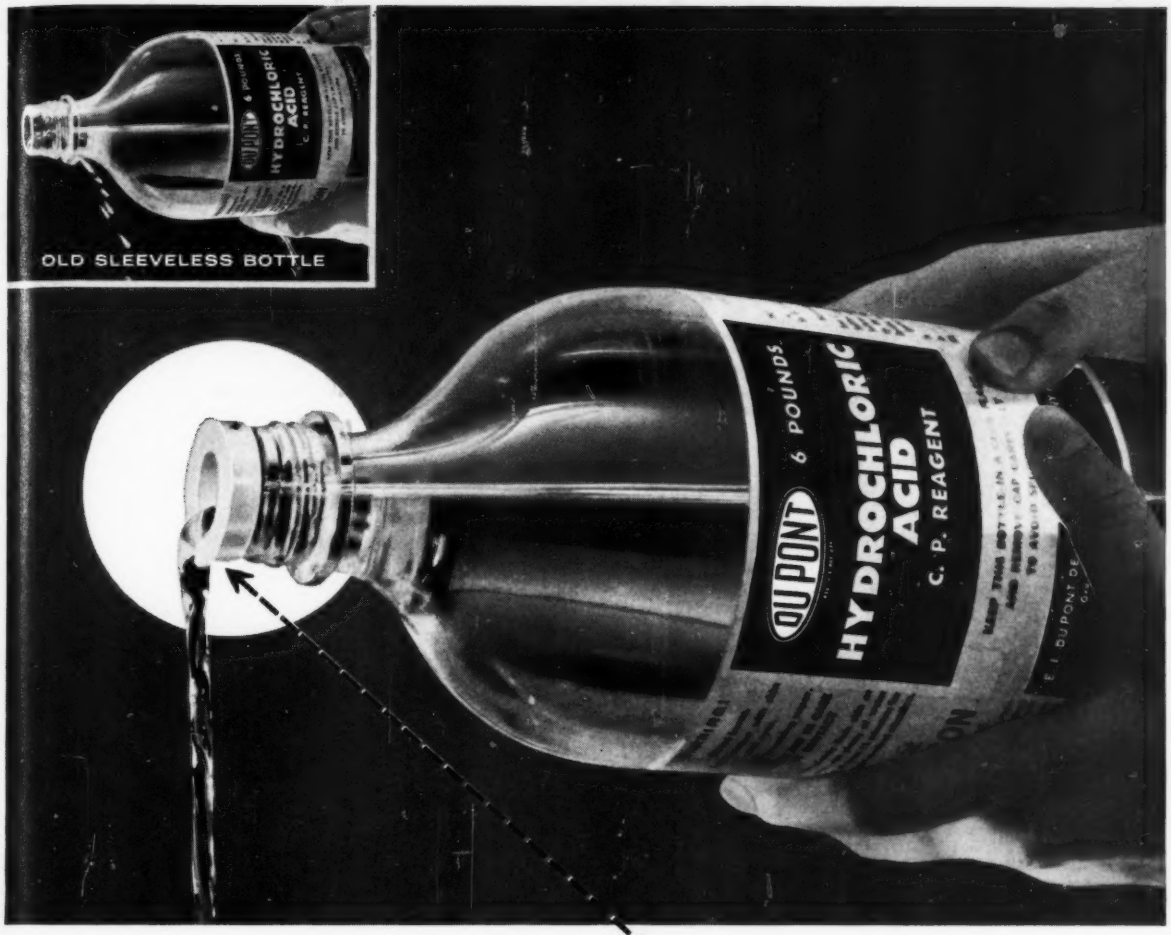

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The dripless sleeve is available at no extra cost on all 5 pint bottles of these Du Pont C. P. Reagents:

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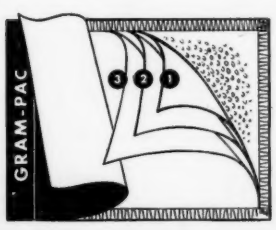
GRAM-PAC

First major improvement in reagent packaging in years

This completely sealed, tough, laminated package eliminates the traditional (and expensive) quarter-pound bottle. It eliminates overlapping sizes, cuts ordering costs, reduces shipping costs and there is no breakage to contend with.

GRAM-PAC permits the packaging of "individual" amounts of reagents for easier distribution and greater laboratory convenience. They are packed 10 PACS to a box and 12 boxes to a case. Eventually, all Fisher Certified Reagents will be available in the inexpensive, contaminant-free GRAM-PAC, including the nearly 200 chemicals specified by the American Chemical Society.

Another "first" from the Fisher Chemical Manufacturing Division . . . to make life easier . . . for you.



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1. **POLYETHYLENE,** next to reagent, for chemical inertness
2. **ALUMINUM FOIL,** for strength and as vapor barrier
3. **ACETATE,** for corrosion resistance

FREE SAMPLE A GRAM-PAC of a Fisher Certified Reagent Chemical is waiting for you. Write to Fisher Scientific, 717 Forbes Street., Pittsburgh 19, Pa., for "Sample GP-16."

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